ECONOMETRIC ANALYSIS OF THE EDIBLE FATS AND OILS ECONOMY

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ECONOMETRIC ANALYSIS OF THE EDIBLE FATS AND OILS ECONOMY

IN THE LAST FEW YEARS a number of studies have appeared in the literature in which the limited-information method of parameter estimation in stochastic models has been used as the primary statistical tool. In all cases that have come to the attention of the authors, these studies have dealt with either a joint or primary commodity.[1] Among the commodities most widely studied by the limited-information, single-equation method of parameter estimation are beef and pork.[2] Some minor commodity relationships such as poultry and eggs have also been investigated with the aid of limited-information estimates.[3] Apparently little or no attention has been given to the use of this technique as a means of evaluating the interrelationships of the secondary or by-product commodities.

These byproducts are frequently in competition with other primary products in their end uses and are subject to wide price variations. A prime example and principal problem area for both producers and consumers is the animal and vegetable fats and oils sector of the economy. Soybean and linseed oil are joint or primary commodities, whereas lard, tallow, and grease are largely byproducts. In many cases a good deal of substitutability exists between these commodities in their final uses.

Wide yearly price variations are the rule rather than the exception in this area. Lard has, for example, ranged from a low of 4.2 cents a pound in 1932 to a high of 22.5 cents a pound in 1957.[4] In addition

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[1] Exceptions may be found in the work of A. J. Rojko, "Econometric Models for the Dairy Industry," *Journal of Farm Economics,* Vol. 39, May 1957, and K. A. Fox, *The Analysis of Demand for Farm Products,* Technical Bulletin 1081, U.S. Dept. Agr., Washington, D.C., 1953.

[2] For example see Vincent I. West, "An Analysis of the Demand for Meat Using a Simultaneous Estimation of Structural Equations," Appendix C in Elmer J. Working, *Demand for Meat,* University of Chicago Press, 1954; William A. Cromarty, "An Econometric Model for United States Agriculture," *Journal of the American Statistical Association,* Vol. 54, Sept. 1959; and Thomas D. Wallace and George G. Judge, *Econometric Analysis of the Beef and Pork Sectors of the Economy,* Technical Bulletin T-75, Oklahoma State University, August, 1958.

[3] For example see George G. Judge, *Econometric Analysis of the Demand and Supply Relationships for Eggs,* Technical Bulletin 307, Storrs Agr. Exp. Sta., University of Connecticut, January, 1954; E. W. Learn, "Estimating Demand for Livestock Products at the Farm Level," *Journal of Farm Economics,* Vol. 38, December, 1956, pp. 1483-91; and M. R. Fisher, "A Sector Model — the Poultry Industry of the U.S.A.," *Econometrica,* Vol. 26, January, 1958.

[4] U.S. Dept. Agr., Agricultural Marketing Service, *The Fats and Oils Situation* (published six times a year).

to long-term gradual shifts during this period, the price of lard has sometimes nearly doubled or been reduced to half the previous year's figure.

The purpose of this investigation was to identify and evaluate the factors responsible for these wide price fluctuations — particularly for lard — through the use of limited-information estimates. The general lack of limited-information estimates on minor commodities furthermore points up the need for an evaluation of this approach in the study of economic relationships in all sectors of the economy.

A large class of commodities falls under the general heading of byproducts. In many cases a firm can show a profit only after the income from the sale of the byproducts is included in its total income. Wide price variations of these commodities contribute substantially, therefore, to the instability of the profit margin of the firm. The end users of these byproducts pay high risk premiums to the market operators as a consequence of this instability. Uncertainty as to the influence of the factors related to the supply of and demand for fats and oils increases the chance of error in the allocation of resources by a producing or processing firm. A misinterpretation of these conditions could and often does lead to severe losses to market operators. The net effect is reduction in returns to the producer or an increase in the price to the consumer. A fuller understanding of the economic structure of the market outlets and sources of supply of the edible fats and oils should contribute to greater price stability for all fats and oils or to methods for better countering the consequences of price variation. Successful application of the limited-information method to the fats and oils sector would imply that additional and perhaps more fruitful application could be found in other areas.

This study will first attempt to evaluate the limited-information method of structural parameter estimation for minor commodities with the available secondary data. It will secondly seek to evaluate those factors that appear to influence the supply of and demand for edible fats and oils.

THE FATS AND OILS ECONOMY

There are some 50 different plant and animal sources of fats and oils. The principal plant sources are coconut and palm trees from the tropics; peanuts (groundnuts), cottonseed, and sesame seed from the warmer climates; olives from the Mediterranean-type climate; and soybeans, linseed, mustardseed, sunflower seed, and rapeseed from the temperate climates. The animal fats come chiefly from slaughtered cattle, swine, and sheep, and from milk, all of which are essentially temperate zone products. In addition, relatively small quantities of fish and whale oil are obtained from marine life in many bodies of water throughout the world.[1]

In the domestic market only a few of these raw materials yield fats and oils that are economically important. Among those that are of prime importance are the cottonseed, soybean, and linseed oils, and butter, lard, tallow, and grease; of lesser importance are the peanut, corn, sesame, olive, sunflower, and marine oils.

Production

All fats and oils are produced jointly or in combination with other commodities. The oilseeds are crushed for the oilcake and oilmeal as well as the oil; the reduction of fish for fish oil also yields fish meal; butter and other milk products are produced at the same time; and the slaughtering of meat animals for meat is accompanied by the rendering of a large part of the fatty tissues for either lard, tallow, or grease.

The length of time that is needed to plan for and produce a marketable product varies from a minimum of three to six months for some of the oilseeds to several years for olive oil. For oilseeds and hogs the plans are normally made a year or more in advance of the marketing date; for beef or dairy herds the production plans are more long range with some built-in flexibility. This makes it possible to determine the quantity of marketable raw material that can be converted into fats and oils at a particular future time.

There is some variation in the quantity of fats and oils that is derived from these materials. These variations are effected by altering the cutout rates in slaughtered animals or altering the processing method of the oilseeds. Such changes are not often carried out in practice. Once the animal or oilseed has been delivered to the processor, the production volume of each of the jointly produced commodities can be determined within narow limits.

Improvements in recovery techniques and methods of extraction have brought about a trend toward higher yields. For example, the minimum oil content to which oilcake can be reduced has decreased from about 5.0 percent to less than 1.0 percent in the past 30 years. In addition, improved plants and animals, more advanced cultural practices, and other technological advancements have also had some effect on the fat and oil yields.

The quantity of a fat or oil that is obtained from the original product can be fairly accurately predicted for any given time period by the equation $x_1 = a_{1.23} + b_{12.3}x_2 + b_{13.2}x_3$, where x_1 is the predicted

[1] United Nations Economic and Social Council, *Studies of Fluctuations in Commodity Prices and Volume of Trade,* Doc. E/CN., 13/L. 34, November, 1956.

Table 1. — Total Production as a Function of the Amount of Raw Materials Processed and of Trend, Specified Oils, 1931-1957

X_1, oil produced	$a_{1.23}$	X_2, material processed	X_3, trend	$S_{1.23}$	$R_{1.23}$
(pounds)		(pounds)	(year)		
Lard	.0002	.1315*	.8100	.0016	.9307*
		(.0131)	(5.000)		
		.9221	.0148		
Tallow and grease	.0000	.0480*	66.27*	.0015	.9779*
		(.0178)	(10.18)		
		.2910	.7038		
Soybean oil	−.0027	.0965*	43.75*	.0010	.9963*
		(.0099)	(10.14)		
		.6957	.3072		
Cottonseed oil	−.0013	.1306*	14.17*	.0006	.9768*
		(.0063)	(1.658)		
		.9031	.3738		
Lindseed oil	.0017	.2307*	−1.379	.0008	.8691*
		(.0285)	(2.359)		
		.8928	−.0643		

* Highly significant ($P<.01$)

The estimating equation in each case is in the form $X_1 = a_{123.} + b_{12.3}X_2 + b_{13.2}X_3$. Under each regression coefficient is given the standard error of that regression coefficient and the corresponding standardized regression coefficient (beta).

Source: Data are from the publications, (a) *Fats and Oils Situation*, United States Department of Agriculture, Agricultural Marketing Service, and (b) Antoine Banna, *Oilseeds, Fats and Oils, and Their Products, 1909-1953*, U.S. Dept. Agr., Agricultural Marketing Service, Statistical Bulletin 147 (June 1954).

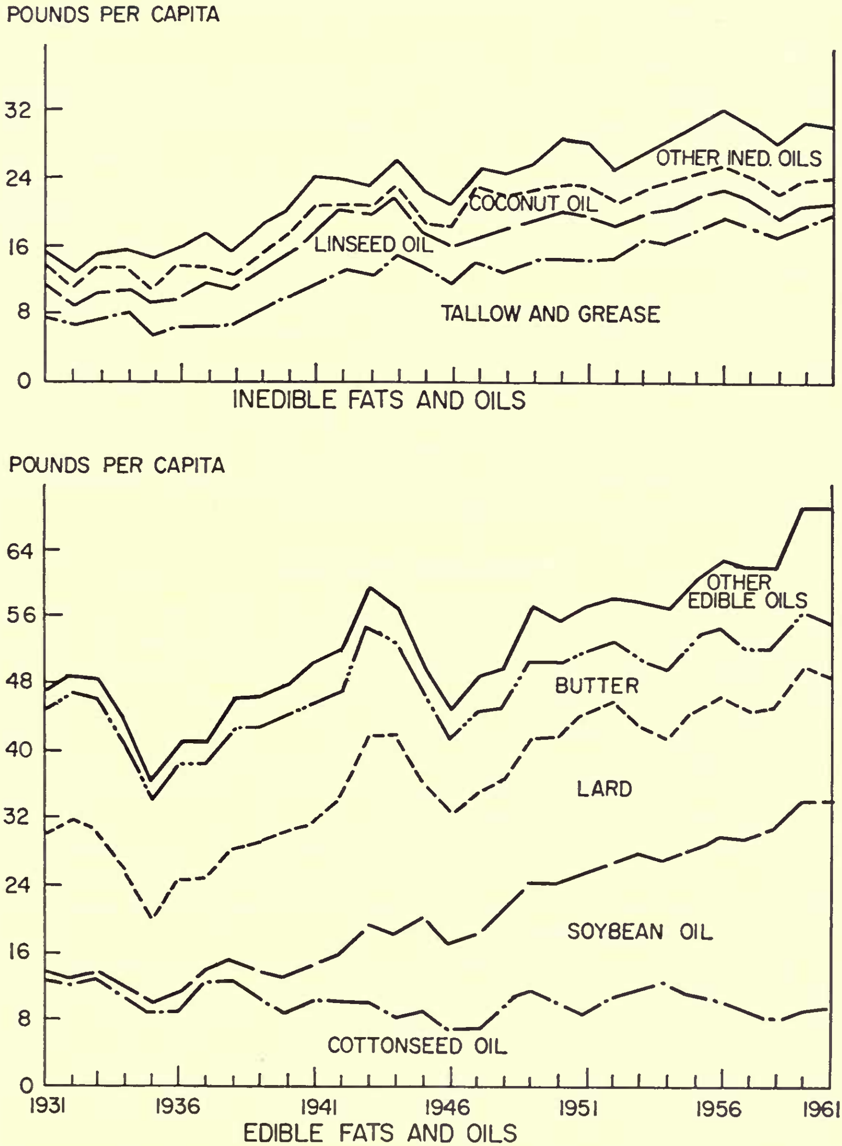
quantity of the fat or oil, x_2 is the quantity of the original product from which the fat or oil is derived, x_3 is time, $b_{12.3}$ and $b_{13.2}$ are the coefficients to be estimated by the method of least squares from past data, and $a_{1.23}$ is the associated constant value.

The multiple correlation coefficient $R_{1.23}$, constant $a_{1.23}$, regression coefficients $b_{13.2}$ and $b_{12.3}$, standard errors of each of these coefficients, standardized regression coefficients $\beta_{12.3}$ and $\beta_{13.2}$, and the standard error of estimate $S_{1.23}$, are given in Table 1.

The unaccounted for variation, which is negligible in most cases, is attributed to the processors having altered the cutout rates in animals or having changed the amount of oil left in the oilcake. These alterations are for the most part a response to fluctuations in the conditions of supply and demand for each of the jointly produced commodities.

The fats and oils economy may be conveniently divided into a larger segment composed of fats and oils that are utilized chiefly as a food or in food products, and a smaller segment that consists of those fats and oils which go largely to industrial users.

The leading food fats and oils produced domestically in the year beginning October 1959 were soybean oil, lard, and rendered pork fat, cottonseed oil, butter, edible beef fats (edible tallow, oleo stock, oleo oil, and oleosterine), corn oil, peanut oil, and olive oil. The leading industrial fats for the same period were inedible tallow and greases,



Production of edible and inedible fats and oils, United States, 1931-1960. (Fig. 1)

tall oil, linseed oil, marine oil (fish, whale, and seal oils), tung oil, and castor oil.[1] Coconut oil is imported or produced from imported mate-

[1] U.S. Dept. Agr., *Fats and Oils Situation, op. cit.*

rial and is important primarily in industrial uses, although it also has some uses as a food.

The division of the fats and oils into two major segments is by no means complete. Large quantities from the food category commonly go to industrial uses, but only very small quantities of the industrial fats and oils go to food uses. Additional processing is necessary to divert an industrial fat or oil to food use and this processing usually involves prohibitive expenditures. On the other hand, a food fat or oil can frequently be used in either division without a great deal of alteration.

The trends and fluctuations in the per capita production volume of the food and industrial fats and oils are presented separately in Fig. 1 for the years 1931 to 1960. The large increase in the domestic production of fats and oils in the years following World War II is attributable, in part, to an increase in the demand for the jointly produced or primary products. The attendant increase in fats and oils production, and to a lesser extent consumption, is illustrated in the graph of domestic supply and distribution. (Fig. 2.)

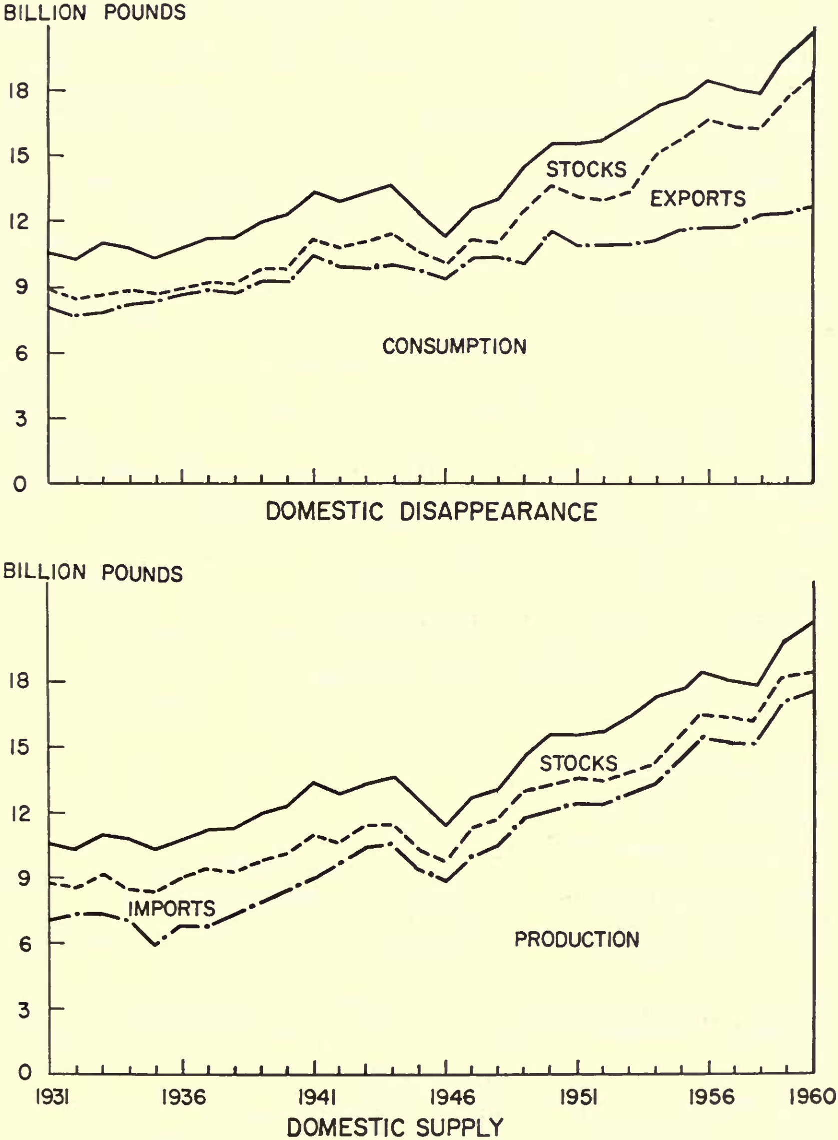
Distribution and Uses

Domestic per capita fat and oil consumption has been quite stable for several decades. From 1931 to 1960 (except during the war years, 1941-1946) the per capita consumption of all fats and oils ranged from 60.7 to 71.5 pounds. Edible food uses ranged from 42.1 to 46.4 and industrial uses 17.8 to 28.4 pounds per capita. (See Fig. 3.) As can be seen from Figs. 2 and 3, domestic production has exceeded consumption in the postwar years. This excess has led to substantial increases in the quantity of fats and oils exported.

Domestic food usage of fats and oils falls into five important categories: lard, shortening, margarine, butter, and salad and cooking oils. The latter use has only recently become important and has not been separately reported prior to 1959.

Fig. 4 gives some idea of the physical flow of the domestic fats and oils and related products. Circles indicate the industry where processing occurred; the rectangular blocks indicate the input and output materials; arrows indicate the direction of the flow. The size of the arrows and the percentages indicate the relative importance of the inputs and outputs at various stages of processing for the year beginning October 1959.

Industrial usage is largely in soap and drying oils. Other industrial uses such as animal feeds are expanding, but none have separately reached substantial proportions of the total. The stability in the total usage of both categories is readily apparent. There have been, however, long-term changes in the food category and more short-term fluctuations in the industrial sector that have been largely compensating. The consumption of lard as lard has decreased substantially but the shorten-

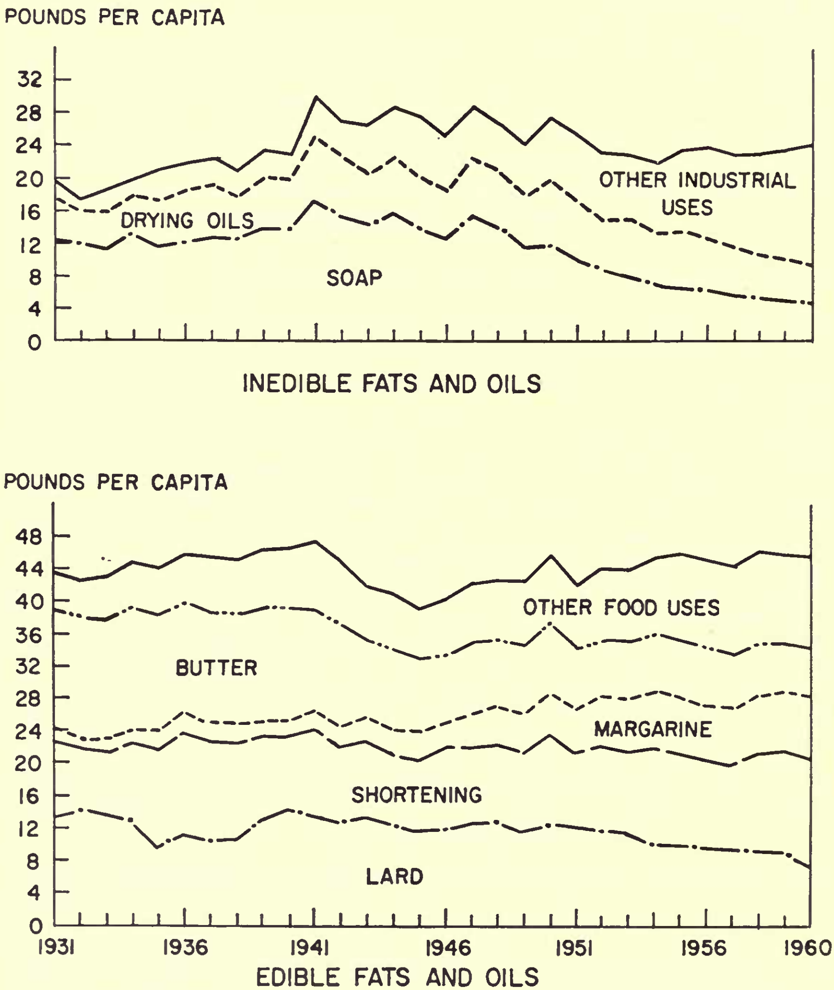


Total domestic fat and oil supply and distribution, United States, 1931-1960. (Fig. 2)

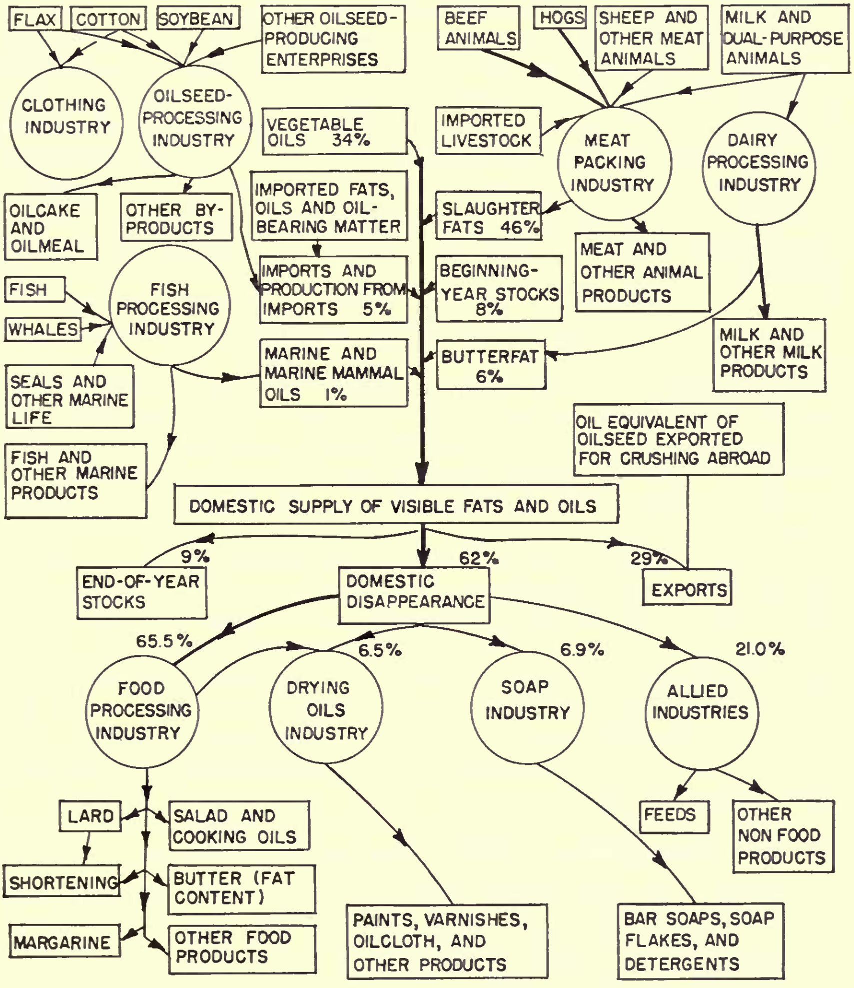
ing substitute has shown a compensating trend. Similar conditions prevail in the industrial sector but within a shorter time period.

These end uses do not, however, reflect the true character of the fats and oils market. Many fats and oils are transformed from one end use to another when supply and demand conditions warrant the shift. For example, lard, soybean oil, and cottonseed oil are major ingredients of many shortening and margarine products. The high degree of interchangeability in the inputs of these end products is apparent from a comparison of the production and consumption figures that are presented in Figs. 1 and 3.

Technological advances in recent years have made possible more diverse and greater substitutability of the edible fats and oils. Increased usage of lard as an ingredient of shortening and margarine is,



Utilization of edible and inedible fats and oils, by commodity or industry classification, United States, 1931-1960. (Fig. 3)



The percentages indicate the relative importance of inputs and outputs at various stages of processing for the year beginning October 1959. (Fig. 4)

in part, attributable to processing methods which have brought about improved products and to more efficient and less costly methods of processing.

Government Policy

Acreage allotments of feed grains, price controls, and income inducements for crops no doubt play a vital role in the supply of and demand for any agricultural commodity. The effect of these factors may either be direct, such as a price-fixing operation, or indirect, such as the production of an alternative crop as a consequence of acreage controls. These effects cannot be adequately measured in any direct quantitative way that is known to the authors. However, the results of governmental operations are still there and should be subjectively incorporated into the study. But this should not cause appreciable difficulty because none of the important fats and oils, except for cottonseed oil in the early fifties, have been directly affected by government operations over the time period of this study. The important indirect effects should enter through exogenous variables and become measurable quantities.

THE STOCHASTIC MODEL

The economic model to be derived below is but one of a large number of possible choices that could represent the lard sector of the economy. The possible alternatives have been restricted to the models whose mathematical form of the equations is linear and whose nonobservable random errors of measurement are assumed to be normally distributed.

The basis of the classification of the variables and of the makeup of the structural equations is formed from economic theory and a knowledge of the industry. The endogenous and exogenous variables included in an equation are specified to have nonzero parameters while the excluded variables which are not in the equation but in the system are specified to have zero parameters. The set of specifications for all equations in the system constitutes the restrictions which specify the economic model to be estimated by the limited-information, single-equation method.

Aggregation and Designation of Variables

The first step in the development of the structural equations is to divide and subdivide the economy into workable aggregates. These aggregates are the variables which appear in the model with at least one nonzero parameter. Since there are both endogenous and exogenous variables in these aggregates, the first division attempts to separate the two types of variables. The lard industry and all closely related industries are contained in the food sector of the economy. Thus, the first division yields the food and industrial or nonfood aggregates.

The second step is to divide the food and industrial sectors into the markets through which their products flow. For a static, closed economy the three markets are defined to be (1) the raw material or farm market, (2) the wholesale or processor market which, in turn, is subdivided into intermediate and secondary parts in order to account for the between-firm movement of commodities, and

(3) the finished goods or retail market. (The market for goods and services is omitted.) However, in a dynamic market one must also consider the storage stocks and the export market as possible outlets. The secondary wholesale market forms the nucleus of the mutually dependent or endogenous variables in this study. The other markets and the nonfood sector of the economy contain most of the determining or exogenous variables.

The third step is to divide the pertinent markets into measurable aggregates. At this point, use is made of economic theory and knowledge of the industry to effect a logical set of variables. According to economic theory, the demand for a given consumer commodity in the equilibrium position is the function of its price, the price of substitute commodities, the price of complementary commodities (in consumption), the price of all other consumer goods, population, personal disposable income, and the demands for storage stocks and exports.[1]

Also according to economic theory, the quantity of a product that an individual firm is willing to produce depends on the prices of the factors of production, the prices received for the products, and the nature of the firm. However, the producer or farmer makes his production plans in the previous production period; consequently the current marketings are predetermined or exogenous factors.[2] Thus, the intermediate wholesaler or processor is the supplier for the secondary wholesale market and, in part, the retail market sector.

The retail market for food is divided into the principal commodity of interest — lard; the substitute commodities — shortening, cooking oils, margarine, and butter; the complementary commodities — meat and baking ingredients; and a group of all other commodities.

This division sets the pattern of the aggregation in the other markets. Each market is basically divided along the same lines. The wholesale market is divided into lard, butter, other food fats and oils, industrial fats and oils, meats, baking ingredients, and other food material; the farm market is divided into hogs, other livestock, oilseeds, dairy products, and other food material; and the storage stocks and the export-import market are divided into the same set of aggregates as those at the wholesale level.

This breakdown gives a complete set of aggregates for the food economy. The price and quantity measures of these aggregates contain the endogenous and most of the exogenous variables that constitute the economic model. The influence of the nondesignated variables enters

[1] Hicks, J. R., *Value and Capital,* Second edition, Oxford (at the Clarendon Press), 1953.

[2] Heady, Earl O., *Economics of Agricultural Production and Resource Use,* New York, Prentice-Hall, Inc., 1952. See also U.S. Dept. Agr., Agricultural Marketing Service, *Farm-Retail Spreads for Food Products,* Miscellaneous Publication 741, November 1957.

through the disturbances. The limiting assumptions that are necessary for such designations are set forth in Hood and Koopmans.[1]

Retail market

The price and quantity measures of the retail aggregates would serve adequately as the basic group of endogenous variables if there were not these three shortcomings: (1) adequate data do not exist for cooking oils and baking ingredients and they must, therefore, be combined with the other food category; (2) the relationship between butter and lard, in addition to being quite weak, is beset by a multitude of controls (private, state, and federal) which inhibit the free operation of economic factors and require that butter also be included in the other food category; and (3) variations introduced into these variables by the retailer's margin or markup obscure the underlying supply and demand relationships.

Wholesale market

The aggregates in the wholesale market are approximately the same as those in the retail classification. Meat and other food categories are the same, but the food fats and oils are transformed into shortening, cooking oils, margarine, other food products and some nonfood products in passing from the intermediate to the secondary wholesale sector. The industrial fats and oils are transformed into drying oils, soaps, and related products in this sector of the market.

The function of the intermediate wholesale market is to take raw material from the farm sector (stocks carried over from the previous period and import material from the foreign sector), submit a product to the secondary wholesale sector for additional processing, provide the carryover stocks necessary for continuous production up to the next harvest period, and export material to meet foreign demand. The secondary sector provides the retail and industrial areas with specially processed fats and oils. Since the wholesaler operates on a margin or markup basis, he is more interested in the prices paid and prices received than in the level of prices.[2] Given the factors of production and an expected set of wholesale prices for the output, the wholesaler will process the material so as to maximize his net profit.

The basic aggregates are, therefore, reduced to the following divisions: lard, shortening, margarine, meat, and other food products. The price and quantity measures of these variables at the wholesale level constitute a major portion of the endogenous variables in the model. The relationships that generate these variables form the structural equations.

The food quantities that are stored, exported, or utilized in the

[1] Hood, W. C., and Koopmans, Tjalling C., *Studies in Econometric Method,* Cowles Commission Monograph 14, New York, John Wiley and Sons, Inc., 1953.

[2] Hicks, *op. cit.*

industrial sector are very small relative to total utilization. Special food groups, of which the fat and oil category is a member, are exceptions to this general rule. Because of their relatively minor importance to total utilization, all measures of these outlets except those of the fat and oil category are assumed to be randomly distributed and included in the disturbances.

The other outlets which are important to the fat and oil category, the export market, industrial market, and possibly storage stocks, will be considered separately and on their relative merits.

The industrial sector combines the fats and oils with other ingredients to form retailable products which bear little or no resemblance to the fat or oil ingredient. These products compete for the consumer dollar in the current period, but because the relationship is weak, the over-all demand for such usage is measured at the wholesale level. At this level the effect enters through the relative supply of the various outlets. Thus, the price and quantity measures of the fats and oils going to industrial uses are considered to be endogenous to the secondary wholesale price and quantity measures.

The effect of storage operations in the current period averages out in the course of a year, and the free carryover is theoretically just sufficient to continue processing operations until the next harvest period. The systematic influence of storage operations is believed to account for a small and most likely an insignificant part of the total variance in retail fat and oil consumption; consequently, storage operations do not warrant separate consideration.

The export market has, on the other hand, become quite important to the fats and oils sector of the economy in recent years (Fig. 2). However, data are not adequate to measure the relationship of foreign factors to the current wholesale market. As a second choice, the quantity supplied to the export market is assumed to be exogenous to the wholesale market. Although this measure is inadequate, it is, in part, correct. The time necessary to process and ship the desired quantities abroad causes current exports to be exogenous to current wholesale prices. However, the time lags are shorter than the observation period and the residual effects could conceivably work back through the economy to the wholesale sector in the current period.

Since export and storage stock prices are essentially the same as the wholesale food and industrial fat and oil prices, there is no need for including separate variables for these factors in the model. Thus, the export quantity is the only additional measure from the wholesale sector to enter the model.

Raw material market

The aggregates of the raw material forthcoming from the farm sector are also quite similar to the aggregates at the wholesale and retail levels. Lard, grease, and pork come from hogs; tallow and other meats come from cattle and other livestock; the remaining food and industrial fats and oils come from the oilseeds; and other food commodities come from other food material.

The supply of the wholesale aggregates depends on the quantity of the raw material produced by the farmer, the imports, and the carryover stocks. Since food producers normally make their production decisions in the previous production period, the quantity of the raw material supplied the processor is largely predetermined in the current period. Vegetables are somewhat an exception to this general rule. Their production period is, in certain cases, short enough to be altered in the current period, but because of the weak relationship between vegetables and edible fats and oils and because little change actually occurs, the production is assumed to be predetermined.

Other fluctuations in the volume of farm marketings can be traced to uncontrollable factors like the weather, national calamities, and other exogenous variables, and to inventory operations by the farmer. The farmer may hold back or deplete his holdings of nonperishable commodities like feed material or livestock as his price expectations change.

If this change in expectations and the subsequent inventory operations are in response to current happenings in the retail market, the affected portion of the quantity of the raw material supplied to the wholesaler is endogenous. However, these inventory operations are short-lived and normally do not carry over into the next market period. Operations that do affect the quantity supplied in the current period are limited in scope and may be assumed to be random in nature without essentially altering the facts.

The quantity of oil that can be extracted from a given quantity of oilseed is known within narrow limits (Table 1). By assuming that the percentage of oil extracted is a predetermined factor, the quantity of oil forthcoming from the oilseed may be considered exogenous. Thus, the production of food fats and oils (other than lard) and industrial fats and oils (other than tallow and grease) is measured after the initial processing step has taken place.

The level of prices paid to the farmer by the wholesaler or processor depends on the level of prices the consumer is willing to pay for the finished goods. The farm demand is, therefore, a derived demand.

The quantity of fats and oils supplied to possible alternative uses depends upon the prices of the alternative products and differences in processing costs. The prices paid to the farmers constitute one of the factors of production. The other factors cannot be measured and must be assumed to be constants or a linear function of time. The production function is also unknown and the product must, therefore, be assumed to be a constant proportion of the raw material intake. Again, the available measures are short of the desired measures.

The other food products are not divided into separate products in this study. There is no need, therefore, to include the factors which determine these parts as separate variables. The aggregate quantity going to the wholesale sector equals the aggregate quantity supplied to the various outlets multiplied by a fixed technical coefficient. Thus the quantity measures of the raw material plus the imports and carryover stocks and the prices paid to farmers for livestock products serve as exogenous variables in the determination of the quantities supplied at the secondary wholesale level.

Other variables

Numerous other variables in the economy beside the endogenous and exogenous variables affect the market relationships in the wholesale food sector. A few of these variables are important and will be included in the model with nonzero parameters; others, not as important, will be included in the disturbances.

As previously mentioned, demand depends on the income of the consumer, his tastes and habits, and other factors. Since the income may take years to adjust to an equilibrium point when a real change occurs, a short-run and a long-run measure should be included in the model. The allocation of the curent available funds among alternative expenditures depends on whether these funds are above or below the income level to which the person has adjusted. Such changes may be measured by some average of the previous income. If the long-run income effect is measured by the previous five-year average, the short-run effect can be measured by the percent this year's income is of the previous five-year average.[1]

Since tastes and habits, technological innovations, and other factors are, for the most part, unmeasurable variables, the element of time is introduced. The inclusion of this variable implicitly assumes that the effect of these factors is a linear function of time. An assumption of this kind is of course not wholly warranted for such a diverse collection of variables; cyclical fluctuations and shifts in the importance of periodic events are not linear functions. Nevertheless, the measure appears to be the best available indicator and is, therefore, included in the model.

The quantity supplied by the intermediate processor to the secondary wholesaler and the retailer depends on the cost of production plus some other variables. Since it sometimes takes years to effect a real change in the cutout of meat to lard or other animal fat in response to a change in relative demand for the products, some long-run measure needs to be included in the model. The previous three-year average of the ratio of the index of lard prices to the index of meat, poultry, and fish prices should adequately reflect such long-run effects.

[1] West, *op. cit.*

Other processors are also slow to respond to changes in the price structure for food; that is, they are slow to alter their output volume or the attributes of their products. Recently, however, demand has increased for foods that are higher on the preference scale and possibly lower in volume and for foods with lower fat content. A measure of such long-run changes in the processing sector is the previous three-year ratio average of the index of food prices to an index of nonfood prices.

Time has already been designated as an exogenous variable to the demand for goods and services. It is again designated as the best available measure for changes in the intrinsic factors that cannot be observed directly but which have some influence on the supply of food and food products. Changes in technical coefficients, market integration, and other factors are not explicitly measurable with the available data. These variables are assumed to change as a linear function of time. Although admittedly inadequate and oversimplified, it is still a convenient measure.

Conditioning of the Variables

Deflation

In order to make the observations of the variables comparable from year to year, all but time have been deflated by appropriate indexes. The wholesale price index (1947-49 = 100) is used to deflate the wholesale price series. The quantity measures, except for the disposable personal income, have been deflated by the civilian population which eats out of domestic supplies. The income measure is deflated by both the consumer price index and the total population to obtain the real per capita disposable income.

An attempt was made to deflate the price measures by indices from the same market level and, where feasible, to choose a deflator that did not contain the price to be deflated as an element. Whenever the price to be deflated was also included in the construction of the deflator, a bias was introduced.[1]

However, the relative importance of the commodity in the construction of the deflator is small in most instances. The direction of the bias depends on the price of the commodity relative to the index. If the price is high relative to the index, the bias is downward; if low, the bias is upward.

The choice of quantity deflators was dictated by the population which makes up the various components of domestic demand for food products. The income variables were deflated by the whole population. Those who eat out of civilian supplies were assumed to have the same

[1] Shepherd, Geoffrey S., *Agricultural Price Analysis* (Second edition, revised), Ames, The Iowa State College Press, 1947.

per capita income as those who do not. (No separate measure exists for the income of people who eat out of civilian supplies.)

Logarithms

The economic relationships between these variables are believed to be multiplicative rather than additive, that is, linear in logarithms rather than linear in "natural " numbers, the common unit of measure. Since some of the fats and oils are extremely substitutive at the wholesale level and, in part, at the retail level, there is only a small change in the quantity of a fat or oil taken for a unit change in its price when the over-all price level of fats and oils is high and the supply is low; whereas, the reverse is true when the price is low and the supply is high — that is, the demand schedule is believed to be curved. However, the curve is quite likely to be proportional; that is, a 1 percent change in the price when the level of the fat and oil prices is either high or low will likely be associated with some constant percentage change in quantity taken. Thus all price and quantity measures are expressed in terms of common logarithms (logarithms to the base ten).

Symbolic representation of the variables

The endogenous variables are expressed as follows:

y_{1t} = Log of the civilian per capita consumption of lard.
y_{2t} = Log of the civilian per capita consumption of shortening.
y_{3t} = Log of the civilian per capita consumption of margarine.
y_{4t} = Log of the civilian per capita consumption of meat.
y_{5t} = Log of the civilian per capita consumption of other foods.
y_{6t} = Log of the civilian per capita industrial use of fats and oils.
y_{7t} = Log of the deflated wholesale price of lard.
y_{8t} = Log of the deflated wholesale price of shortening.
y_{9t} = Log of the deflated wholesale price of margarine.
y_{10t} = Log of the deflated wholesale price of red meats.
y_{11t} = Log of the index of the deflated wholesale price of other food.
y_{12t} = Log of the index of the deflated wholesale price of industrial fats and oils.

The exogenous variables are expressed as follows:

z_{1t} = Log of the previous five-year arithmetic average of deflated per capita disposable income.
z_{2t} = Log of the percentage this year's deflated per capita disposable income is of the previous five-year arithmetic average of deflated per capita disposable income.
z_{3t} = Time.
z_{4t} = Log of the civilian per capita quantity of fats and oils and oil equivalent of oilseed exported.
z_{5t} = Log of the civilian per capita liveweight of hogs slaughtered.

z_{6t} = Log of civilian per capita liveweight of cattle, calves, sheep, and lambs slaughtered.

z_{7t} = Log of pounds per capita (civilian) of food fats and oils supplied other than butter and lard.

z_{8t} = Log of deflated index of prices received (1910-14) by farmers for meat animals.

z_{9t} = Log of pounds per capita (civilian) of industrial fats and oils produced excluding inedible tallow and grease.

z_{10t} = Log of the deflated index of per capita food production of food other than meat animals.

z_{11t} = Log of the ratio of the wholesale price index of lard to the wholesale price index of meats, poultry, and fish for the previous three years.

z_{12t} = Log of the ratio of the index the wholesale price of processed food is to the index of wholesale price other than food and farm products for the previous three years.

The Equations

The development of the supply and demand equations of the above set of endogenous and exogenous variables requires a set of specifications about the values of the parameters. A variable is excluded by specifying the associated parameter to have a zero value. A variable is included when its parameter is assumed to be nonzero.

Economic theory and special knowledge are used to justify the inclusion or exclusion of certain variables from certain equations. The demand equations contain in general the price and quantity measures of the commodity in question, the price of complements and supplements, the price of all other commodities, long-run and short-run measures of income, the export influence (if any), and time. The supply equations contain, essentially, the price and quantity measures of the commodity, the price of alternative products, the price paid for the raw material (if appropriate), the quantities of the raw material available for processing, possible alternative export outlets, time, and (where appropriate) some measure of past influence on the secondary processing sector.

Demand for lard

Lard and shortening are closely related substitutes in consumption. When lard consumption goes up, shortening consumption tends to go down. This means that the consumers demand a rather stable quantity of cooking fat for which either shortening or lard fulfills the need, the lower-priced commodity being preferred to the higher-priced one unless some other factor interferes. However, shortening has become a larger part of the combined total because other factors have not remained the same. The shortening manufacturers have put on intensive advertising campaigns and have made known the fact that they have a more standardized product. Also shortening has been sold in attractive and convenient packages for some time while lard has only recently been put into such containers. After considerable loss of retail outlets, the lard manufacturers improved their product, adopted similar merchandising techniques, and became more competitive with shortening manufacturers. The price of shortening is, therefore, a major component in the demand for lard equation.

Although margarine and lard are not close substitutes in their finished form, they are closely related through the factor market. The fats and oils that are used in the manufacture of shortening are also used in the manufacture of margarine. An increase in the demand for margarine will bring forth, other things being equal, larger quantities of margarine and, in turn, reduce the fats and oils available to produce shortening. The smaller quantities of shortening cause its price to increase and consequently make lard more attractive to the consumer. Thus, the substitute for substitute principle requires that the price of margarine also enter the equation.

The fats and oils going to industrial uses also include a large quantity of food fats and oils. Soybean oil, for example, is an excellent drying oil. Because of a relationship like that of margarine to lard, the industrial fats and oils wholesale price index is also included in the equation.

Meat and lard are weak complements in consumption. The preparation of certain meat dishes requires the use of a fat or oil in the cooking process. Lard or a substitute for lard is used for this purpose. The price of meat is, therefore, included in the equation.

Other food products compete with lard for the consumer dollar. Assuming that the consumer is going to spend only a certain quantity of his income on food, the amount that goes to the various food aggregates must, therefore, be budgeted among the available food items. That portion which is allocated to lard depends on the nature of the consumers' preferences and the prices of the various components.

The effects of income changes on the demand for lard are slow to work out in practice; consequently, short-run and long-run effects are included in the equation.

Foreign demand may be either high or low. A shortage of lard abroad is not necessarily accompanied by an increase in demand. In order to meet the desires of the people, there must be some commodity or income that can be used in exchange for the desired commodity. A shortage of such exchangeable items exists abroad. However, the United States has instituted a number of programs in recent years that have attempted to rid the country of burdensome surpluses and feed undernourished people in other countries. A measure of the effect that such programs and the existing foreign demand have on the domestic retail demand for lard is postulated as the quantity of fats and oil equivalent of oilseed exported.

The inclusion of time as a variable requires the implicit assumption that the aggregate of all other unaccounted-for factors is additive and linear in its effect on the demand for lard.

Thus, the demand for lard is postulated to be represented by

$$\begin{aligned}(1)\quad & \beta_{11}y_{1t} + \beta_{17}y_{7t} + \beta_{18}y_{8t} + \beta_{19}y_{9t} + \beta_{1,10}y_{10t} + \beta_{1,11}y_{11t} \\ & + \beta_{1,12}y_{12t} + \gamma_{10} + \gamma_{11}z_{1t} + \gamma_{12}z_{2t} + \gamma_{13}z_{3t} + \gamma_{14}z_{4t} = u_{1t}\end{aligned}$$

where the nonzero parameters of the endogenous and exogenous variables are β's and γ's, respectively except for γ_{10}, which is the constant value, and the u_{it}, which is the disturbance. The parameters that appear in the equation are to be estimated by the limited-information, single-equation method.

Supply of lard as lard

The theory of the firm asserts that the supply of a commodity in a closed economy depends on the prices of the production factors, the prices of the finished goods, and the production function.[1] Since the export market plays an important role in the fats and oils market, the restriction of a closed economy is relaxed and the measure of the export influence is included as a causal variable.[2]

The only available factor price included in the supply relation is that which is paid to farmers for meat animals. The other factor prices are assumed to be constant in real value terms or a linear function of time, which is included in the equation as a measure of such influence and of gradual changes in technical coefficients.

The alternative outlets for portions of the pork carcass are lard, shortening, meat, and other animal products. Lard is an ingredient of many shortening compounds and, as such, affords a separate outlet; the percentage of the pork carcass going to fats or to meats is confined within narrow limits, but some substitution is possible; and the other animal products (bristles, blood, and the like) are not measured because little or no variation is possible. The wholesale price of meat, poultry, fish, and of lard and shortening is postulated to regulate the quantities going to the alternative outlets.

Although processors sometimes alter their cutout in response to price changes in pork and lard, their response cannot be instantaneous, especially if the over-all operation remains profitable and the price change is small. The packers' response may lag for months or possibly years, depending on the efficiency of the management personnel and policies of the company.

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[1] Hicks, *op. cit.*

[2] Mosack, Jacob L., *General Equilibrium Theory in International Trade*, Bloomington, The Principia Press, Inc., 1944.

In addition, the producer gradually alters the physical attributes of the hogs produced whenever a market preference is shown for animals with particular attributes. The effects of these delayed responses are postulated to be measured by the previous three-year average of the ratio of the wholesale price of lard to the wholesale price of meat, poultry, and fish.

The level of the over-all supply of pork products depends on the number and weight of hogs marketed by the producer. Since this quantity is essentially a predetermined factor, it is included as an exogenous variable.

The export market provides a convenient outlet for surplus lard. Since it has already been demonstrated that the only available measure of this outlet is the quantity of fats and oils that is actually exported, this variable is postulated to represent the effect of the export market on the supply of lard as lard at the secondary wholesale level.

The supply of lard as lard is, therefore, postulated to be represented by

$$(2) \qquad \beta_{21}y_{1t} + \beta_{27}y_{7t} + \beta_{28}y_{8t} + \beta_{2,10}y_{10t} + \gamma_{20} + \gamma_{23}z_{3t} + \gamma_{24}z_{4t} + \gamma_{25}z_{5t} + \gamma_{28}z_{8t} + \gamma_{2,11}z_{11t} = u_{2t}$$

where the symbolic representation of the variables is defined as above.

Demand for shortening

The considerations contributing to the demand-for-lard equation apply equally well to its close substitute, shortening. The quantity of shortening demanded depends on the wholesale price structure, per capita disposable income, the foreign sector, and time. The wholesale price of lard is included. The retail price of margarine appears because of the slight substitution effect of the finished commodities and the similarity of their respective ingredients, that is, the oils used in their production. The price of industrial fats and oils reflects the possibility of the ingredients being utilized in the industrial sector rather than the food sector. The other variables are included for the same purpose that they were included in the demand for lard.

The demand equation for shortening is, therefore, postulated to be

$$(3) \qquad \beta_{32}y_{2t} + \beta_{37}y_{7t} + \beta_{38}y_{8t} + \beta_{39}y_{9t} + \beta_{3,10}y_{10t} + \beta_{3,11}y_{11t} + \beta_{3,12}y_{12t} + \gamma_{30} + \gamma_{31}z_{1t} + \gamma_{32}z_{2t} + \gamma_{33}z_{3t} + \gamma_{34}z_{4t} = u_{3t}$$

Supply of shortening

The quantity of shortening supplied at the retail level depends, to a large extent, on the quantity of food fats and oils other than butter that is available for blending purposes in the wholesale sector. The per capita supply of these food fats and oils excluding lard and butter is taken as a measure of this variable.

The firms that utilize the fats and oils allocate the available quantities among the alternative outlets so as to maximize profits. Since the quantity that is exported is assumed to be given, the relative prices of the possible outlets — lard, shortening, margarine, and industrial uses — determine, in part, the quantity that goes to shortening products. Time is again included to represent the changes in the nonmeasured factors.

The retail supply of shortening is, therefore, postulated to be represented by

$$(4) \quad \beta_{42}y_{2t} + \beta_{47}y_{7t} + \beta_{48}y_{8t} + \beta_{49}y_{9t} + \beta_{4,12}y_{12t} + \gamma_{40} + \gamma_{43}z_{3t} + \gamma_{44}z_{4t} + \gamma_{47}z_{7t} = u_{4t}$$

No lag price variable is included in this equation because it is believed that most shortening manufacturers respond quite rapidly to price changes among the ingredients. These adjustments "soften" the impact of major changes in any one fat or oil on the over-all fats and oils economy.

Demand for margarine

Margarine competes directly and indirectly with both lard and shortening. The direct relationship is quite weak because margarine is a poor substitute for shortening and lard as a cooking fat. The indirect relationship is, however, quite strong. The ingredients of margarine are essentially the same as the ingredients for shortening; therefore, through the substitute principle a strong relationship exists. Thus, the same set of retail prices and attendant variables applies as well to margarine as to lard and shortening.

The retail demand for margarine is, therefore, postulated to be

$$(5) \quad \beta_{53}y_{3t} + \beta_{57}y_{7t} + \beta_{58}y_{8t} + \beta_{59}y_{9t} + \beta_{5,10}y_{10t} + \beta_{5,11}y_{11t} + \beta_{5,12}y_{12t} + \gamma_{50} + \gamma_{51}z_{1t} + \gamma_{52}y_{2t} + \gamma_{53}y_{3t} + \gamma_{54}y_{4t} = u_{5t}$$

Supply of margarine

The quantity of margarine supplied at the retail level depends, like the quantity of shortening, on the quantity of food fats and oils that is available for blending purposes in the wholesale sector; the price of margarine, lard, shortening, and industrial fats and oils; time; and the exported quantity of fats and oils and oil equivalent of oilseeds. The large increase in the quantity of margarine supplied over the period of this study is principally attributable to improvement in its flavor and texture, to a lowering of legislative barriers by most states, and to changes in the tastes and habits of consumers. These factors are largely associated with trend.

Thus, the supply of margarine is postulated to be represented by

$$(6) \quad \beta_{63}y_{3t} + \beta_{67}y_{7t} + \beta_{68}y_{8t} + \beta_{69}y_{9t} + \beta_{6,12}y_{12t} + \gamma_{60} + \gamma_{63}z_{3t} + \gamma_{64}z_{4t} + \gamma_{67}z_{7t} = u_{6t}$$

Again, no lag variables are included in the equation. It is believed that margarine manufacturers, like shortening manufacturers, respond quickly to current price and quantity changes in the fats and oils market.

Demand for meat

Pork and other red meats are highly substitutive in the consumer's diet and are considered a commodity group. The over-all demand for red meats and its relationship to other commodities are determined in this equation and will form a basis of comparison with other studies. Since lard is jointly produced with pork, the complement and substitute for complement principles hold in the determination of the basic relationship between the meat and the fat and oil industries. Thus, the wholesale prices of the commodities produced from fats and oils and the wholesale price of industrial fats and oils are included in the meat demand equation.

Meat accounts for a major portion of the consumer's food expenditure (about 20 percent) and is in competition with all other foods for the food dollar. The wholesale price of meats and other foods is postulated to reflect this relationship. Although consumers tend to retain their past consumption habits, a real change in the income of an individual must eventually be reflected in his purchasing habits. For this reason the long-run and short-run effects of income changes are included in the equation.

Time is included to represent any trends that occurred in the market structure during the period of time covered by this study.

Thus, the demand for meats is postulated to be given by

$$\beta_{74}y_{4t} + \beta_{77}y_{7t} + \beta_{78}y_{8t} + \beta_{79}y_{9t} + \beta_{7,10}y_{10t} + \beta_{7,11}y_{11t} + \beta_{7,12}y_{12t} + \gamma_{70} + \gamma_{71}z_{1t} + \gamma_{72}z_{2t} + \gamma_{73}z_{3t} = u_{7t} \tag{7}$$

Supply of meat

The quantity of meat supplied depends largely on the quantity and liveweight of meat animals marketed by the producer in the current period.[1] That portion of the carcass which may be put to more than one use by the intermediate firms depends on the relative prices of the products and the prices paid for the factors of production. The index of prices paid to farmers for meat animals is again the only measurable factor price. The wholesale prices of lard, shortening, meat, and industrial fats and oils are postulated to reflect the economic pressures for some particular cutout ratio.

As in the case of lard and pork, the packer can alter the cutout rate of nonpork meats to fatty tissue, but the degree of variation is low and the tendency is to standardize the cutout procedure. Apparently there is not the consumer resistance to fat being left on beef cuts that

[1] Fox, *op. cit.*

there is for pork. If any resistance does exist, the wholesale price ratio of lard to pork for the previous three-year period is postulated to measure such changes.

Thus, the supply of meat at the wholesale level is postulated to be represented by

$$(8) \quad \beta_{84}y_{4t} + \beta_{87}y_{7t} + \beta_{88}y_{8t} + \beta_{8,10}y_{10t} + \beta_{8,12}y_{12t} + \gamma_{80} + \gamma_{83}z_{3t} + \gamma_{85}z_{5t} + \gamma_{86}z_{6t} + \gamma_{88}z_{8t} + \gamma_{8,11}z_{11t} = u_{8t}$$

The lagged average wholesale price ratio of lard to meats, poultry, and fish is included in lieu of the lagged average wholesale price ratio of all slaughter fats to all meats which would be appropriate in the meat supply equation. If the latter measure were used in this equation and the former in the lard supply equation, it would be impossible to make estimates of the structural parameters with acceptable accuracy because of the multicollinearity between the two variables.[1] For this reason the ratio of lard price to meat, poultry, and fish prices is used in both equations.

Demand for other foods[2]

In order to round out the system of equations for food at the wholesale level, foods other than lard, shortening, margarine, and meats are grouped together and studied as a unit. This group constitutes approximately 75 to 80 percent of the food expenditures of the consumer. Thus, this equation is a close approximation to the over-all demand for food.

Analogous to the demand equations for the other products, the demand for other food is a function of the index of wholesale price for this food group, the prices of the other commodities, and disposable personal income. Since the demand for food is subject to changes in tastes, eating habits, and other trends, time is also included in the equation.

The demand for other food is, therefore, postulated to be represented by

$$(9) \quad \beta_{95}y_{5t} + \beta_{97}y_{7t} + \beta_{98}y_{8t} + \beta_{99}y_{9t} + \beta_{9,10}y_{10t} + \beta_{9,11}y_{11t} + \beta_{9,12}y_{12t} + \gamma_{90} + \gamma_{91}z_{1t} + \gamma_{92}z_{2t} + \gamma_{93}z_{3t} = u_{9t}$$

Supply of other food

The supply of food is dependent primarily on the quantity marketed by the producing or farm sector. Since food products are measured by various units (pounds, bushels, gallons, and the like), it is impossible to represent the volume of farm production adequately by any single

[1] Tintner, Gerhard, *Econometrics,* New York, John Wiley and Sons, Inc., 1954.

[2] Girshick, M. A., and Haavelmo, Trygve, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," *Econometrica,* Vol. 15, No. 2, April 1947.

unit of measure. By using a set of prices in a base period and multiplying each quantity measure by its appropriate price and adding results, an index of food marketings in constant dollars can be constructed for each year included in the study. The effect of changes in farm marketing of raw materials from which fats and meats are derived may mostly be removed by subtracting the index of the farm marketings of livestock from the index of total food marketings according to the relative importance of the former. The residual is put on a per capita basis and expressed in index form to represent the volume of farm marketings of other foods relative to the base period.[1]

A large quantity of food never reaches the retail market because of spoilage and the lack of a ready market. Costs relative to expected returns control the percentage of food wasted in this manner by regulating the movement of food out of the producer and wholesale markets into the retail channels. An index of the wholesale price of this group of foods determines, in part, the quantity sold at the retail level. A wholesale price index of meat, poultry, and fish is also included in order to account for the effect that its price may have on the supply of other food. Time is included in the equation to account for any trends that may exist.

Some processors in this category are slow to respond to changes in the price structure for food, that is, they are slow to alter their volume of output or the attributes of their products in line with consumer demand. The desire of consumers for foods with a lower fat content has probably not been fully exploited by processors to date as the per capita fat intake has remained fairly stable over the past several years. The previous three-year average of the ratio of the index of wholesale food prices to the index of wholesale prices of all commodities other than food and farm products is believed to reflect the long-run adjustments in the processing sector.

The supply of other food is, therefore, postulated to be represented by

$$(10)\quad \beta_{10,5}y_{5t} + \beta_{10,10}y_{10t} + \beta_{10,11}y_{11t} + \gamma_{10,0} + \gamma_{10,3}z_{3t} + \gamma_{10,10}z_{10t} + \gamma_{10,12}z_{12t} = u_{10t}$$

Demand for industrial fats and oils

The demand side of the system of equations for food is made complete by the inclusion of an equation for the industrial fats and oils. Since all fats and oils are in some degree substitutive for one another, the demand for industrial fats and oils is closely related to the demand

[1] Grove, Ernest W., and Cannon, Margaret F., "Index Numbers of Farm Marketings and Home Consumption," U.S. Dept. Agr., Agricultural Marketing Service, *Agricultural Handbook No. 109*, Washington, D.C., July 1956

for food fats. The demand for industrial fats and oils depends, for the most part, on the level of industrial activity. This is believed to be adequately measured by consumer income. Consumer income is primarily derived from the sale of productive resources to firms operating in the industrial sector.

Other measures are available which would more accurately reflect industrial activity, but they have not been included in this equation because of their close relationship to the income variables which are necessary to some of the above equations. Since including two closely related and supposedly exogenous variables would probably bias the parameter estimates, only one measure is included in the model.

The other measures that enter the demand equation for this commodity are the wholesale price variables of lard, shortening, meats, and of course, industrial fats and oils. Time is again included to account for whatever trends may exist in this sector of the economy. Also, variables quite similar to variables already included in other equations are excluded from the model.

The foreign sector is quite important in the determination of the domestic price of industrial fats and oils. The principal ingredient of the industrial fats and oils is inedible tallow and grease. The tremendous upsurge of the post-war livestock industry created a considerable surplus of inedible fat. The surplus was shipped abroad where post-war prosperity had created a suitable outlet at favorable prices. The quantity of fats and oils and oil equivalent of oilseeds exported serves as a measure of this activity.

The wholesale demand for industrial fats and oils is, therefore, postulated to be represented by

$$(11)\quad \beta_{11,6}y_{6t} + \beta_{11,7}y_{7t} + \beta_{11,8}y_{8t} + \beta_{11,10}y_{10t} + \beta_{11,11}y_{11t} + \beta_{11,12}y_{12t} + \gamma_{11,0} + \gamma_{11,1}z_{1t} + \gamma_{11,2}z_{2t} + \gamma_{11,3}z_{3t} + \gamma_{11,4}z_{4t} = u_{11t}$$

Supply of industrial fats and oils

The supply of industrial fats and oils is largely dependent on the production of their jointly produced commodities. The principal commodity from which approximately two-thirds of the industrial fats and oils volume is derived is nonpork meat. Since the price of fats and oils has little to do with the quantity of meat produced, the per capita liveweight of meat animals marketed other than hogs is used as a measure of production. The per capita liveweight of hogs is also included in the equation in order to account for the grease which is reported with tallow. The prices of the respective products and the factors of production regulate whatever changes occur in the cutout rates. The wholesale price of industrial fats and oils and the wholesale price of meats, lard, and shortening are used to reflect the variation in these rates and the alternative outlets of the interchangeable fats and oils.

The remaining quantity of nonfood fats and oils is derived from a number of sources; the principal ones, flaxseed and marine life, are joint products with other commodities. It would be impossible to ascertain the quantities of all of the original material marketed because of the variety of sources and the differences in their units of measure. As a second choice, the remaining nonfood fats and oils are measured at the next step of the market structure. The per capita supply of these fats and oils, therefore, serves as the measure of the remaining quantity of fats and oils utilized by the industrial sector.

The latter measure is considered to be an exogenous or predetermined variable when, in actual fact, some variation in the percentage yields is possible by altering the processing technique in some of the commodities. This variation is, however, very small when compared to the variation in the whole industry. The slight error should not be discernible in the final analysis.

In recent years about half of the inedible tallow and grease production has been shipped to foreign countries. At first the foreign market served as a convenient outlet for surplus production in the post-war years. Increased prosperity abroad also increased demand for fats and oils so that the outlet compares favorably to domestic outlets.

By including time to account for any trends, the supply of industrial fats and oils is, therefore, postulated to be represented by

$$\begin{aligned}(12)\quad & \beta_{12,6}y_{6t} + \beta_{12,7}y_{7t} + \beta_{12,8}y_{8} + \beta_{12,10}y_{10t} + \beta_{12,12}y_{12t} + \gamma_{12,0} + \gamma_{12,3}z_{3t} \\ & + \gamma_{12,4}z_{4t} + \gamma_{12,5}z_{5t} + \gamma_{12,6}z_{6t} + \gamma_{12,8}z_{8t} + \gamma_{12,9}z_{9t} = u_{12t}\end{aligned}$$

THE STRUCTURAL RELATIONSHIPS

Description of the Model

The economic model presented in the previous section comprises the complete equation system — 12 endogenous variables in the 12 equations. The endogenous variables are expressed as functions of 12 exogenous variables and 12 disturbances. The inclusion or exclusion of certain variables in specific equations is accomplished through specifications about the value of the associated parameter. Each variable appears at least once in the model with a nonzero parameter and, in most cases, more than once. Each disturbance includes the effect of the exogenous variables that are excluded from the model.

The nonzero parameters of these equations can be estimated from knowledge of the distribution of the endogenous and exogenous variables and from the assumptions of the disturbances. The equations must, however, first meet the identification requirements before the parameters can be estimated by the limited-information, single-equation method. These requirements are formally stated in the references[1] and essentially reduce to a counting procedure; that is, the number of linear

[1] Hood, *op. cit.*

restrictions on the parameters in any one question (the number of zero parameters) must be at least equal to the number of equations in the system less one.

The demand-for-lard equation contains, for example, 11 nonzero parameters; consequently, 13 of the total of 24 variables (12 endogenous variables) are excluded. Since the number of excluded variables is greater than the number of structural equations less one, that is,

$$13 > 12 - 1, \tag{13}$$

the equation is overidentified. This means that the number of linear restrictions on the parameters of this equation is greater than was necessary to achieve identification.

Repeated application of this rule reveals that all the equations are overidentified. The parameters of these equations can, therefore, be estimated by the limited-information, single-equation method.

Data Limitations

Appropriate data were collected for these variables from a number of sources and are summarized in the appendix tables. These observations were taken from what is believed to be the best available source. Although the war years are included in the series, they were not used in the model. Most of the data came from official publications of the United States Departments of Agriculture and Labor, and the Bureau of Census. Other data had their origin in the publications or files of the people who are responsible for these reports.

There are a number of limitations to these data. To begin with, appropriate data exist for relatively few of the possible equation systems that could be considered valid. The above outlined model was dictated, in part, by the available data.

Another data limitation is the failure of most economic time series to meet the stringent requirements of the economic model. The data-gathering procedure of the Agricultural Estimates Division of the United States Department of Agriculture for commodities (the basic source of much of the data) is chiefly centered around varied questionnaires and market reports. This approach is of doubtful accuracy because of the biases introduced by human failures and the method of index number construction. The fixed weights of the indexes that are constructed from these reports impart an upward bias in the published figures.[1] In addition, inadequate coverage of the markets has an unknown effect on the final estimates.[2]

[1] Staehle, H., "A Development of the Economic Theory of Price Index Numbers," *Review of Economic Studies*, Vol. 2, No. 3, June 1935.

[2] U.S. Dept. Agr., Agricultural Marketing Service, "Major Statistical Series of the U.S. Department of Agriculture," *Agricultural Handbook No. 118*, Vol. 1-9, 1957-58.

The figures from the Bureau of Labor Statistics of the United States Department of Labor (another basic source of data) are compiled from a judgment sample of 46 cities selected from the 3,000 towns and cities of the United States that range in population from 2,500 to the 8,000,000 of New York City. A sample of chain and independent retail food dealers' selling prices is taken by field representatives and serves as a basis for the index number construction. A description defining the item to be priced is used by the agents in data collection.[1] These data are then summarized and the figures published. Again, the resulting indexes are subject to the biases inherent in index number construction. Errors of judgment and mistakes may also influence the final values, although it is hoped that these errors have been kept to a minimum by the data-collecting agencies and that errors entering the figures are cancelled out when the data are totaled. If a substantial data error does enter the model, it is not known at this time what effect it will have on the final result.[2]

Demand Equations

The limited-information estimates and the standard errors of the demand equations are given in Table 2. The coefficients b_{ig} and c_{ik} are the estimates of the parameters β_{ig} and γ_{ik}, respectively, where i is the number given to the equation in the previous sector and g or k is the number of the endogenous or exogenous variable with which the coefficient is associated. The standard errors are given by σ_{ig} or σ_{ik}, where i, g, and k again have the same meaning.

The equations have been normalized with respect to the quantity variables. Since logarithmic relationships were used for all variables except time, the coefficients (except the coefficients asociated with time) can be read directly as elasticities.

A cursory examination of the coefficients and the standard errors immediately reveals an obvious fact: a number of the coefficients (especially the endogenous coefficients) are opposite in sign to the postulated behavior and a large proportion of those that are of appropriate sign are not of reasonable magnitude. Further, the standard errors indicate that most of the endogenous and about half of the exogenous coefficients are not significantly different from zero at the 5-percent level.

According to the theory of consumer preference,[3] the demand curve for a finished good should be negatively sloped; the cross-elasticity coefficients for substitutes should reflect a direct relationship, and for complements, an inverse relationship; and the short-run and long-run

[1] U.S. Dept. of Labor, "Store Samples for Retail Food Prices," *Monthly Labor Review,* Vol. 66, January, 1947.

[2] Neiswanger, W. A., and Yancey, T. A., "Parameter Estimates and Autonomous Growth," multilith report, Urbana, University of Illinois Department of Economics, 1958.

[3] Hicks, *op. cit.*

Table 2. — Summary of Estimates of the Demand Equations

	b_{i1}	b_{i2}	b_{i3}	b_{i4}	b_{i5}	b_{i6}	b_{i7}	b_{i8}	b_{i9}	b_{i10}	b_{i11}	b_{i12}
b_{1g}	−1.0						−.337	+5.998	−4.859	+.286	−14.237	−3.310
σ_1							1.970	13.715	12.293	1.676	42.084	10.269
b_{3g}		−1.0					+.711	−.832	+.347	+.264	−1.287	−.310
σ_3							.357	1.051	.936	3.15	3.591	.826
b_{5g}			−1.0				+.242	+3.278	−1.680	+437	−6.705	−2.724
σ_5							.731	3.410	2.960	−.632	10.867	2.658
b_{7g}				−1.0			−.156	+.146	+.159	−.553	+.583	+.082
σ_7							.109	.183	.208	.106	.632	.082
b_{9g}					−1.0		+.120	−1.316	+.540	−.437	+.827	+.553
σ_9							.187	.315	.331	.173	1.056	.139
b_{11g}						−1.0	−.097	+.783		−.032	−2.959	−.417
σ_{11}							.270	.445		.240	1.821	.444

	c_{i0}	c_{i1}	c_{i2}	c_{i3}	c_{i4}	c_{i5}	c_{i6}	c_{i7}	c_{i8}	c_{i9}	c_{i10}	c_{i11}	c_{i12}
c_{1k}	+12.662	+9.662	+2.217	−.1691	−1.380								
σ_1		2.914	1.799	.0502	.472								
c_{3k}	+3.006	−.275	+.455	+.0106	−.055								
σ_3		.397	.410	.0076	.065								
c_{5k}	+8.394	+3.678	+.384	−.0339	−.769								
σ_5		.921	.796	.0168	.151								
c_{7k}	+.430	+.360	+.223	−.0004									
σ_7		.114	.113	.0021									
c_{9k}	+1.471	−.271	+.072	+.0032									
σ_9		.193	.192	.0035									
c_{11k}	+4.233	+1.172	+.421	−.0137	−.277								
σ_{11}		.294	.333	.0057	.049								

income effects are expected to be positive but may be negative in the case of an inferior commodity.

Demand elasticities

Of the six demand coefficients (b_7, b_8, b_9, b_{10}, b_{11}, b_{12}), one is positive and five are negative. Of the five coefficients which agree in principle with economic theory (that is, in being negatively sloped) only one is significantly different from zero. The coefficient of the demand for meat b_{710} and the associated standard error have a value of $-.55$ (.11). This coefficient compares favorably with but is slightly lower than the value obtained in previous studies in this area by Fox,[1] Working,[2] and Tintner.[3]

The values of the elasticity of demand for lard b_{17} and shortening b_{38} were computed to be $-.34$ (1.97) and $-.83$ (1.05), respectively, which is not significantly different from zero but can be compared with the value of $-.60$ which Stone reported for lard for the United Kingdom.[4]

The computed elasticities of demand for margarine and the industrial fats and oils were -1.68 (2.96) and $-.42$ (.44), respectively. These also are not significantly different from zero. No studies are available for comparison of these estimates.

Cross elasticities

No studies report comparable cross elasticities of demand (all other b_{ig} values in the demand equations). The basis of judging the computed values must, therefore, rest on (1) knowledge of the relationship, and (2) the internal consistency of the estimates. Consistency between the estimates can be checked by the Hotelling relation,

$$p_i q_i \eta_{ij} = p_j q_j \eta_{ji}, \tag{14}$$

which states that the value of the *i*th commodity $p_i q_i$ times its cross elasticity η_{ij} with the *j*th commodity equals the value of the *j* commodity times its cross elasticity η_{ji} with the *i*th commodity.

The mean values of the price and quantity measures and one of the cross-elasticity coefficients are substituted into the formula and the other cross elasticity is computed. This computed value is $\eta_{ij} = (p_j q_j / p_i q_i) b_{ji}$. In this equation and in equation 14 the subscripts are to be regarded as commodity indices rather than the variable designations given earlier.

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[1] Fox, Karl A., "Factors Affecting Farm Income, Farm Prices, and Food Consumption," *Agricultural Economics Research,* Vol. 3, July 1951.

[2] Working, Elmer J., *Demand for Meat,* Chicago, The University of Chicago Press, 1954.

[3] Tintner, Gerhard, "Static Econometric Models and Their Empirical Verification, Illustrated by a Study of the American Meat Market," *Metroeconomica,* Vol. 2, December 1950.

[4] Stone, Richard, *The Measurement of Consumers' Expenditures and Behavior in the United Kingdom, 1920-1938,* Cambridge University Press, 1954.

Commodity	*Quantity Variable*	*Price Variable*
Lard	y_1	y_7
Shortening	y_2	y_8
Margarine	y_3	y_9
Meat	y_4	y_{10}
Other Foods	y_5	y_{11}
Industrial Fats and Oils	y_6	y_{12}

The cross elasticity of demand for margarine with respect to the price of lard would thus be

$$\eta_{57} = (\bar{y}_1\bar{y}_7/\bar{y}_3\bar{y}_9)b_{19} = -6.1397.$$

This is to be compared with the value of $b_{57} = +.242$. In Table 3 the equation and variable designations are subscripts for both η and b. In equation 14 either η_{ij} or η_{ji} could have been supplied from the coefficients previously estimated. Only one such substitution has been made, since the resulting ratio of b_{ij} to η_{ij} would be the same.

Table 3. — Estimated Cross Elasticities Compared With Cross Elasticities Computed by the Hotelling Relation

	b_{i7} η_{i7}	b_{i8} η_{i8}	b_{i9} η_{i9}	b_{i10} η_{i10}	b_{i11} η_{i11}
b_{3j} η_{3j}	+.711 +5.339				
b_{5j} η_{5j}	+.242 −6.1397	+3.278 +.493			
b_{7j} η_{7j}	−.156 +.823	+.146 +.085	+.159 +.995		
b_{9j} η_{9j}	+.120 −4.090	−1.316 −.415	+.540 −1.525	−.437 +582	
b_{11j} η_{11j}	−.097 −1.576	+.783 −.166	(no comparison) −1.026	−.032 +.136	−2.959 +.916

A test of the significance of the difference of these values could be constructed[1] but the inclusion of the wide standard errors of the cross elasticities in the computation of the confidence intervals would make the measure meaningless. Consequently, subjective comparisons are more appropriate. The comparisons reveal that the two statistics b_{ij} and η_{ij} are, in general, very dissimilar. An hypothesis that the terms are different must be accepted in almost every case.

[1] Drake, Albert E., *Econometric Analysis of the Demand and Supply Relationships for Lard at the Retail Level,* Ph.D. thesis, University of Illinois, August 1958.

According to economic theory the cross elasticity of substitutes is positive and of complements, negative. It is known that some products (like lard and shortening) are substitutes and others (like meat and other foods) are complements. An examination of the signs of the coefficients reveals the inconsistency of these estimates with economic theory. The magnitude of a number of these estimates is also unreasonable. In addition, the standard errors are, in almost every case, as large as the estimates. Consequently, the cross elasticities in the demand equations are considered to be inappropriate estimates of the market relationships which they are supposed to represent.

Income elasticities

The results in Table 2 show that the long-run and the short-run income terms are with but two exceptions positive. The exceptions, c_{31} and c_{91}, or the long-run income demand for shortening and other food, are inappropriate estimates. According to economic theory,[1] the income terms may be either positive or negative but, if negative, the product with which the coefficient is associated is considered to be an inferior commodity; that is, an increased income decreases the quantity of the good taken if other things remain equal. However, shortening and other foods are not considered to be inferior products and the coefficient is not significantly different from zero; consequently, the estimate is considered inappropriate.

The other terms vary considerably in their acceptability. About half of the coefficients are significantly different from zero, but the magnitude of some of the measures is questionable. In addition, the long-run term is expected to be more elastic than the short-run term.[2] This difference holds in four cases, the income demand for lard, margarine, meat, and industrial fats and oils. In the other equations, the short-run term is opposite in sign.

Lard, shortening, margarine, and the industrial fats and oils, all have short-run income elasticities which are not significantly different from zero at the 5-percent level of confidence. The values, + 2.217 (1.799), + .455 (.410), + .384 (.796), + .421 (.333), respectively, are lower in three out of four cases than the +.96 which Armore computed for food fats and oils other than butter and lard.[3] The latter three terms are inelastic and consistent with each other, that is, of approximately the same size.

The income terms in the meat equation are opposite to the postulated relative magnitudes; that is, the short-run term is more elastic than the long-run term. The short-run and long-run estimates, +.36

[1] Hicks, *op. cit.*

[2] West, *op. cit.*

[3] Armore, Sidney J., "The Demand and Price Structure for Food Fats and Oils," U.S. Dept. Agr., *Technical Bulletin 1068,* Washington, D.C., 1953.

(.11) and +.22 (.11), respectively, are also more inelastic than the values reported by Working.[1] The standard errors of the two terms are, in addition, quite high. The short-run term is barely nonsignificant at the 5-percent level while the long-run term is quite significantly different from zero; however, the confidence interval covers a wide range of acceptable values. The values are considered to be inappropriate estimates of the true parameters.

The +.07 (.192) short-run elasticity for other foods is below the range of other studies in this area.[2] The sign of the long-run coefficient is opposite from the postulated behavior and is not significantly different from zero.

Coefficients of time

The coefficients associated with the time variable (Table 2) follow the direction of the trend in some of the observational variables (see appendix tables). The coefficient and the trend are negative for the per capita lard and the industrial fats and oils uses in the domestic market and positive for per capita shortening and other food. The coefficients of the first group are significant at the 5-percent level while those for the second group are not significant. The coefficients of margarine and meat go opposite to their trends and are not significant.

The general failure of the cross-elasticity coefficients to be significantly different from zero may indicate that the relationships are related to the time variable, and the coefficients associated with time reflect, in part, these influences. If these excluded variables had been measured and included in the model, the structural relationships of the food sector would have undoubtedly been more accurately represented. However, time is the best available measure of these factors.

Export elasticities

As postulated, the increase in demand for fats and oils from the export market resulted in a decrease in the quantity taken in the domestic market. The negative coefficients of the export variable − 1.38 (.47), − .055 (.065), − .77 (.15), − .28 (.05), for the four fats and oils equations show this effect clearly. All but the coefficient in the shortening equation is significantly different from zero.

However, the nature of the measurement of this variable leaves much to be desired and limits its usefulness. Quantities going to the export sector would no doubt be difficult to measure in the current time period and its influence could not be readily measured. An index of prosperity of key nations abroad would likely serve as a more useful measure. The significance of the measures used does, however, point up the importance of the foreign sector in the determination of domestic demand for fats and oils.

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[1] Working, *op. cit.*

[2] Girshick, *op. cit.*

Supply Equations

The estimated values of the parameters in the supply equations are reported in Table 4 along with the standard errors. The designations have somewhat the same interpretation as in Table 2.

Supply elasticities

The coefficients of the supply equations are in half the equations different in sign from the postulated behavior and the theory of the firm.[1] According to economic theory, the supply elasticities are expected to be positively sloped; that is, a change in the price of the *i*th commodity is supposed to bring about a positive change in the supply of that commodity. However, three of the coefficients indicate that the quantity change is inversely related to a price change. In fact, one such change, b_{1011}, is significantly different from zero at the 5-percent confidence level. Such changes are opposite to the postulated behavior.

None of the positively sloped coefficients are significantly different from zero. In addition, there is no consistency in the magnitudes of the estimates. Quantity response of individual fats and oils to price changes within this sector is believed to be more elastic than the response to a similar over-all price change. Once the production volume of the raw material is determined, changes in the demand for a particular end use should result in a reallocation of the available fats and oils to their best alternative uses. Such changes should be reflected in positive supply coefficients. Only the supply coefficient for margarine, +1.29 (1.22), has this attribute and this value is not significantly different from zero.

There is also another element to consider. If the supply coefficients are interpreted to mean that additional quantities of fats and oils material are supposed to be forthcoming from the producers at increased prices, the negative coefficients may not be too irrational. Fats and oils supply is essentially fixed during one observation period and any shortage (or surplus) will be compensated for by an opposite change in prices. Thus, while prices may not influence the over-all fats and oils supply that is available, they are influenced by the available supply; that is, a short supply is sold at relatively high prices and, at other times, a surplus must be disposed of at fairly low prices. The degree of mutual dependence of price and quantity may, therefore, be quite low in the current period.[2]

Cross elasticities

The sign of the cross elasticities depends on whether the commodities are substitutes or complements in production or consumption or

[1] Hicks, *op. cit.*

[2] Cochrane, Willard W., *An Analysis of Farm Price Behavior,* The Pennsylvania State College, School of Agriculture, Progress Report 50, May 1951.

Table 4. — Summary of Estimates of the Supply Equations

	b_{i1}	b_{i2}	b_{i3}	b_{i4}	b_{i5}	b_{i6}	b_{i7}	b_{i8}	b_{i9}	b_{i10}	b_{i11}	b_{i12}
b_{2g}	−1.0						−.621	+1.197		−1.075		
σ_2							.276	.474		.908		
b_{4g}		−1.0					+.717	+.011	−.746			−.431
σ_4							.298	.639	.762			.277
b_{6g}			−1.0				−.337	+.943	+1.285			−1.315
σ_6							.410	.890	1.222			.389
b_{8g}				−1.0			+.136	−.104		−.035		+.005
σ_8							.066	.129		.233		.103
b_{10g}					−1.0					−.224	−1.444	
σ_{10}										.136	.484	
b_{12g}						−1.0	−.657	+.059		+1.053		+.612
σ_{12}							.419	1.171		2.342		.683

	c_{i0}	c_{i1}	c_{i2}	c_{i3}	c_{i4}	c_{i5}	c_{i6}	c_{i7}	c_{i8}	c_{i9}	c_{i10}	c_{i11}	c_{i12}
c_{2k}	+.816			−.0148	+.101	+.082			+.632			−.092	
σ_2				.0031	.063	.218			.234			.111	
c_{4k}	+1.482			+.0001	−.198			+.535					
σ_4				.0043	.058			.205					
c_{6k}	+.496			+.0341	−.187			−.349					
σ_6				.0060	.078			.281					
c_{8k}	+1.334			+.0052		+.372	+.147		−.156			+.054	
σ_8				.0006		.042	.042		.055			.029	
c_{10k}	+5.561			−.0119							+.904		−.835
σ_{10}				.0013							.250		.224
c_{12k}	−.459			−.0027	−.085	−.240	+.374		−.494	+.202			
σ_{12}				.0068	.097	.344	.290		.483	.243			

some combination of these relationships. If the products are substitutive in consumption, a change in the price of one commodity leads to a positive change in the quantity of the other commodity; if complementary, the positive price change is associated with a negative change in quantity. If the products are substitutive in production, an increase in the price of one leads to a decrease in the output of the other; if complementary, an increase in the price of one is associated with an increase in the supply of the other. Since products and factors from which they are made are considered to be substitutes, an increase in the price of the factor leads to a decrease in the supply of the product. There are other possible combinations but these relationships are the only ones covered by the model.[1]

An examination of the cross elasticities in Table 4 reveals that the terms are, in many cases, in accordance with the postulated behavior but, in only a few instances, are significantly different from zero. Some of the coefficients that have the appropriate sign are not, however, of reasonable magnitude. For example, lard and shortening are substitutes in consumption and, according to the above relationship, an increase in the price of shortening should be associated with a positive change in the quantity of lard. The coefficient b_{28} has the proper sign but the magnitude is unreasonably high. The value of + 1.20 (.48) means that the quantity of lard supplied to the retail market changes 1.2 percent in response to a 1.0-percent change in the price of shortening. However, the coefficient b_{47} which shows the estimated response of shortening to an increase in the price of lard has a more reasonable value +.717 (298) which is also highly significantly different from zero.

The other terms are either different from the postulated behavior or not significantly different from zero. The only set of coefficients with any apparent consistency in direction are those that are associated with the shortening equation. The signs of the cross-elasticity coefficients of this category are as postulated and of reasonable magnitude, but the supply elasticity is smaller than one would expect with a highly substitutive set of commodities as inputs.

Coefficients of time

The coefficients associated with the time variable (Table 4) again follow the direction of the trend in most of the observational values of the quantity variables (see appendix tables). The per capita quantity of lard supplied has decreased and the coefficient that is associated with time is negative; the per capita quantity of shortening, margarine, and meat supplied has increased and the associated coefficients are positive. Industrial fats and oils and other food are exceptions to this general rule. The time coefficient for industrial fats and oils is negative

[1] Hicks, *op. cit.*

and the trend is positive; the time coefficient for other food is negative and there is no perceptible trend in the observational values. Furthermore, the time coefficients for lard, margarine, meat, and other foods are highly significantly different from zero.

Apparently, there are a number of nonmeasured and, most likely, pertinent factors excluded from the supply equations. Changes in the technological advances have certainly occurred, but outside of the variable of time, have not been measured or included in the model. If such measures could have been adequately represented, the unexplained variance would likely have been substantially reduced.

Export elasticities

The coefficients of the export variable are all highly inelastic and have relatively small standard errors (Table 4). However, only two coefficients, c_{44} and c_{64}, are significantly different from zero at the 5-percent confidence level.

A substantial trend exists in the export measure, but unless time or some other variable accounted for this trend, it has little or no influence on the quantities of fats and oils supplied the retailers. Apparently, the domestic needs are taken care of by the suppliers and the extra or remaining quantities are exported. Thus, the export market has little measurable effect on the domestic supplies at the retail level.

Quantity elasticities

The quantity of the raw material supplied the wholesaler or processor should be positively related to the quantity of the finished goods suppled the retailers; that is, the finished goods should be related to the raw material by some technical coefficient or ratio. The coefficients of z_5, z_6, z_7, and z_{10} are, with three exceptions, significantly different from zero. The first exception, c_{25}, has a value of $+.083$ (.218) which indicates correctly that increased per capita hog slaughter increases the available supply of lard. The second exception is c_{67} in the equation for margarine. The coefficient is not significant and is different from the postulated sign. The other exceptions are in the industrial fats and oils equation.

Most of the other coefficients which are significantly different from zero are of reasonable magnitude. Only one of the coefficients which are of the postulated sign is greatly different from the expected values. A 1.0 percent increase in the quantity of cattle, calves, sheep, and lambs slaughtered is likely to increase the wholesale meat supply by more than $+ .147$ (.042) percent. The other values appear to have the appropriate sign and are of reasonable magnitude.

Factor elasticities

Only one factor price is included in the model and it has three nonzero coefficients, c_{28}, c_{88} and c_{128}. According to economic theory, an increase in the price of a factor leads to an increase in the price of commodities that are complementary in consumption with the product that is produced in the employment of this factor, and to a decrease for those factors that are considered as substitutes.

The quantity of meat animals marketed by the farmer is very weakly related to the price received for the lard to be produced from this factor. Thus, lard and marketed meat animals are complements in consumption and the coefficient c_{28} should be positive. The value of +.63 (.23) seems to be a reasonable approximation of the postulated relationship.

Since the factor z_8 and the meat product y_4 are considered to be substitutes,[1] the coefficient c_{88} is also of the postulated sign. The value −.156 (.055) is, however, a rather low estimate. The other coefficient, c_{128}, is not significantly different from zero and is opposite to the postulated sign for complements.

Elasticities of the lagged variables

The lagged relationship between the ratio of the previous three-year average of lard to meat prices does not apparently affect the supply of either lard or meats. The coefficients c_{211} and c_{811} are different from the postulated sign and the standard errors indicate that the coefficients are not significantly different from zero.

However, the coefficient $c_{10,12}$, which is a similar measure of the relation between food prices and nonfood prices, is significantly different from zero but opposite to the postulated behavior. A 1 percent increase in the price of food relative to nonfood commodities for the previous three years is not expected to cause a .835 (.224) percent decrease in the quantity of food supplied.

Nonidentification Tests

The size of the standard errors in a number of the coefficients and the sign of the estimates themselves immediately raise the question of the identification of the equations. Since the necessary condition was fulfilled by every equation in the model (equation 13), the sufficiency condition is questioned. Is the value of the determinant of the coefficients of the excluded variables for each equation actually zero?

The wide standard errors indicate that a number of such coefficients do not, in actual fact, differ significantly from zero. The necessity of using such coefficients to meet the sufficiency condition casts doubt on the identification of the equations.

Tests for nonidentification are given by each of the following asymptotically equivalent forms:[2]

$$T \log (\zeta_1 \zeta_2) \qquad T (\zeta_1 + \zeta_2 - 2)$$

where T is the number of observations and ζ_1 and ζ_2 are the smallest

[1] Hicks, *Ibid.*

[2] Hood, *op. cit.*

Table 5. — Tests for Nonidentification

Equation number	Degrees of freedom	T log ($\zeta_1 \zeta_2$)		T ($\zeta_1 + \zeta_2 + 2$)	
		Chi-square values	Probability level	Chi-square values	Probability level
1	3	4.21	.14	10.94	.02
2	5	10.02	.08	29.32	.01
3	3	1.93	.61	4.78	.20
4	6	6.69	.36	18.18	.01
5	3	3.56	.16	9.01	.04
6	6	9.18	.15	27.85	.01
7	6	6.36	.18	18.20	.01
8	4	6.47	.18	20.08	.01
9	4	6.00	.20	16.17	.01
10	8	7.91	.45	22.19	.01
11	4	5.26	.27	14.99	.01
12	3	4.19	.41	10.86	.02

and next to the smallest eigen value in the solution of the separate equations.[1] The tests are distributed according to χ^2 with $K_{**} - G_\Delta + 2$ degrees of freedom (K_{**} is the number of excluded exogenous variables and G_Δ is the number of included endogenous variables in the equation). A rejection of the hypothesis of nonidentification does not necessarily mean that the equation is identified. The rejection does, however, lead one to conclude that the equation is identified. The test results are given in Table 5.

The two tests differ considerably in their χ^2 value and probability level. The nonidentifiability hypothesis is strongly rejected for every equation by the T ($\zeta_1 + \zeta_2 - 2$) test while the T log ($\zeta_1\zeta_2$) test does not reject any of the 12 equations at the 5-percent probability level. The tests are not conclusive and no conclusion can be drawn about the nonidentification of most of the equations.

The power of the test is, however, rather weak. The $\underline{\Delta}$ degree polynominal p (ζ) of the determinal equation has as many roots as there are endogenous variables in the equation. A graph of the polynominal would reveal the position of the roots or eigen values relative to each other and amplitude of the fluctuations between them. In most cases the two smallest roots ζ_1 and ζ_2 would appear close together; the amplitude of the curve between them is small. The closer the roots are to each other and to their minimum value, the more likely they are to be indistinguishable.[2]

[1] Drake, *op. cit.*

[2] Frisch, Ragnar, *Statistical Confluence Analysis by Means of Complete Regression Systems,* Publikasjon nr. 5 Oslo, Universitetets Økonomiske Institutt, 1934.

Auto-correlation Tests

Another and perhaps more important factor in the size of the standard errors is the possibility of auto-correlations among the disturbances. These values represent the unaccounted-for variation in the endogenous variable to which each equation is normalized. The residuals are supposed to represent the effects of all other variables not defined in the stochastic model and are specified to have the properties of a normally distributed random variable.

A weak and partial test of the assumption of independence in these random variates is given by a slightly altered simple correlation between the lagged disturbances. If the correlation is sufficiently high, the null hypothesis of independence is rejected. However, failure to reject the hypothesis by this test does not mean that independence has been demonstrated.

Many additional tests have been devised to examine the possibility of more complicated functional dependence among these values. However, the simple, linear relationship of lagged variables is believed to be adequate for tests of serial independence.

The ratio of the covariance of the lagged value to the variance of the unlagged values was used in the computations. The results of this test along with the 5- and 1-percent significance levels are given in Table 6 for the 1-, 2-, and 3-year lagged disturbances.

The 1-year lagged auto-correlations are all negative but only two are significantly different from zero at the 5-percent probability level. All but one of the 2-year lagged values are negative and 7 of the 12 values are significant at either the 5- or the 1-percent probability level. The 3-year lagged values are in no particular order and none are significant.

Table 6. — Tests for Auto-correlations

Equation number	One-year lag	Two-year lag	Three-year lag
1	−.015	−.391*	+.156
2	−.350	−.234	−.055
3	−.175	−.297	−.046
4	−.165	−.382*	+.042
5	−.121	−.444*	−.013
6	−.027	−.533**	+.015
7	−.404*	+.031	+.012
8	−.420*	−.134	+.202
9	−.131	−.396*	−.280
10	−.015	−.253	+.088
11	−.146	−.660**	+.208
12	−.256	−.417	+.207

* Significant at the 5-percent level ($P<.05$).
** Significant at the 1-percent level ($P<.01$).

The preponderance of negatively auto-correlated values in the first two columns of the table suggests the possibility that the excluded variables do have some influence on the results. The rationale of negative auto-correlations is found in the cobweb theorem, whereby prices that go up in one period tend to go down in the succeeding period or periods or vice versa; that is, expectations of the consumers or businessmen may follow a cyclical pattern of some sort.

This influence is not believed to be severe in the 1-year lagged values. However, the auto-correlations of the 2-year lagged values, which are fairly low in all but two cases, are significant in 7 of the 12 equations.

The effect of these significant auto-correlations will likely increase the size of the standard errors. However, Aitken has demonstrated that this increase is smaller than it should be for single equation models. The computed standard errors are underestimates of the true error.[1] The effect of auto-correlations on multi-equation models has not been extensively investigated. If the effect is comparable, the standard errors obtained in this study are likely underestimates of the true error terms.

In addition to the above mentioned factor, there is another possible cause of these low but significant auto-correlations. The deflation of the price variables by the wholesale price index and the quantity variables by the civilian population may possibly have introduced variation that is inherent in the deflators. The auto-correlations would then become a function of the deflators and not a function of excluded variables.

IMPLICATIONS OF THE FINDINGS

The data provided in Tables 2 through 6 do not allow us to accept or reject the stochastic model as an adequate representation of the edible fats and oils sector of the economy. The inconsistency of the estimates of the structural parameters as to direction and magnitude as well as the level of significance in most of the values casts doubts on the reliability of the model as a means of predicting the behavior of the variables in response to changes in the market.

The causal factors behind these shortcomings are not readily apparent. Three possible reasons can be suggested: (1) the stochastic model is an inadequate representation of the food sector of the economy, (2) the data do not adequately represent the variables which enter the model, or (3) the method of handling the data has led to biases which obscured the true nature of the estimates of the structural parameters. Let us look at these three in turn.

[1] Aitken, A. C., "On Least Squares and Linear Combinations of Observations," *Proceedings of the Royal Society of Edinburgh,* 1934-35.

Shortcomings of the model

Most of the inadequacies of the model center around the selection of variables to measure postulated relationships and the necessity of combining influential factors into aggregates which obscure their effects on the variables of interest. The foreign sector was, for example, measured by the quantities of fats and oils exported. A more useful measure would have been some index of relative prosperity abroad.

In another instance, domestic demand for industrial fats and oils was measured by consumer disposable income rather than some measure of industrial activity. This choice was made necessary by the requirement that the exogenous variables must be mutually independent of each other. Measures of industrial activity would likely have resulted in multicolinearity with the income variable and violation of the implicit assumption of independence among the exogenous variables.[1]

Butter and other cooking oils were included in the other food aggregate for different reasons. Butter is beset by governmental controls and, as such, the price does not fluctuate freely in response to supply and demand conditions. Other cooking oils were not broken down into measurable price and quantity variables until 1959.

Despite these and other shortcomings, the model should have been adequate for making estimates of the parameters of the equations for lard, shortening, and margarine. The important coefficients of these equations should not have been unduly influenced by the above-mentioned shortcomings.[2]

Shortcomings of the data

The reports on which estimates of the quantity of edible fats and oils produced and consumed are based are often incomplete and apparently inaccurate. Frequent revisions of the data are made in response to more detailed and more accurate market reports. These revisions are sometimes carried back over several years. The outward signs and conversations with industry personnel lead one to conclude that the quantity data used in this study are only rough approximations of the true values.

The price data are no doubt of much better quality. However, the data were intended to represent domestic demand when, in actual fact, the prices that were used frequently originated in only one market.

[1] Hood, *op. cit.*

[2] Several alternative models at both the retail and wholesale level were tried with much the same results as reported here. See Drake, *op. cit.*, for an example.

The chosen market was Chicago, which is near the central part of the country.

The price structure of this market probably differs only slightly from the true structure when the yearly averages are used as the basis of comparison — the observation period of this study. However, these small variations are likely to have contributed to the wide variation in the estimated values.

Where no adequate time series existed for measuring the postulated behavior, the closest available observation was taken. The meat, poultry, and fish price index was, for example, used as a measure of the price of meat. No doubt some sensitiveness was lost as a result of this choice.

The data limitations are serious and are believed to be primarily responsible for the shortcomings in the estimates of the structural parameters.

Conditioning of the data and requirements of the method

In an attempt to make the observations comparable from year to year, the price and quantity variables were deflated by appropriate indexes and the resulting values were put into logarithms. The resultant values and time were used as the measures of the variables that entered the equations.

The limited-information, single-equation method of estimation of the structural parameters requires that the data which enter the model come from a population of values for each of the years and that the distribution function of each of these several populations is but one of a set of such functions. Each population is specified to have a multivariate normal distribution with a zero mean for the random errors and a constant variance which is the same for all populations.

Two consequences of these requirements are the implicit assumptions that the years for which data are taken to be included in the sample are random selections for all possible years, and that tastes, technology, habits, and other unmeasured factors differ from year to year by only a random error — that is, these factors are essentially constants or a linear function of time.

As can easily be ascertained neither of these two assumptions are warranted. In the time period covered by this study considerable changes took place in tastes and habits of the consumers and technological advances have been made by the manufacturers. These changes are likely to be nonlinear. Technological improvements are often instituted over a short period of time, whereas the time variable implies a more gradual adoption of the innovation. These shortcomings have no doubt contributed to the failure of the model to provide estimates of reasonable magnitude that are in line with the postulated values.

Equations which represent major or primary commodities also yielded poor estimates of the structural parameters. This shortcoming is likely traceable to two related factors: (1) minor commodity variables that would be included in the disturbance or in measures of larger aggregates have been specified to have nonzero parameters in the major commodity equations, and (2) other minor commodity variables that are included in the model but not in the equation. Kuznuts has argued that limited-information estimates are influenced by the latter condition.[1]

The auto-correlations in the two-year lagged disurbances (Table 6) point up the failure to meet the requirement of independence in the exogenous variables. However, in those equations in which the auto-correlations were low, the estimated values of the structural parameters had the same shortcomings as in those equations which exhibited the significant auto-correlations. Consequently, the failure to meet the assumptions of the method is apparently not the whole cause of the poor results but only a contributing factor.

Thus, the requirements of the limited-information, maximum-likelihood method of parameter estimation of structural equations are apparently too stringent for effective use in stochastic models of the economic relationships of the minor or byproduct commodities. The disaggregation that is necessary to construct a model of this form leads to the measurement of variables that are such close substitutes that they become near duplicates in their price variations. Furthermore, the failure of the data to meet the requirements of the method leads to inconsistent estimates whose standard errors are frequently as large or larger than the coefficients.

In addition, this complete disaggregation requires a very large number of observations in order to have a sufficient degree of freedom to make parameter estimates. Such requirements lead to long time series in which the economic system is constantly evolving in response to changes in the institutional factors.

Better data over a shorter period of time should lead to more valid estimates. At the present, however, the useful estimates that can be attained with this method are apparently limited to major commodities in which large aggregates of commodities form the variables that enter the stochastic model. More precise data are apparently available for these products.

[1] Kuznuts, G. M., "Measurement of Market Demand with Particular Reference to Consumer Demand for Food," *Journal of Farm Economics,* Vol. 35, December 1953.

SUMMARY

This study investigated the feasibility of using the limited-information, single-equation method of parameter estimation to ascertain the structural relationships of the secondary or byproduct commodities. A stochastic model of the edible fats and oils sector of the economy, with particular emphasis on lard at the wholesale market level, was used as an example. (Wide price and quantity variations made this particular choice appropriate.) The flow of the various commodities, the pattern of changes, and the institutional arrangements were followed over the period of study.

The stochastic model was specified to contain the aggregates lard, shortening, margarine, meats, other food, and industrial fats and oils for which the price and quantity measures served as the endogenous variables of the system. The exogenous variables were taken as the predetermined factors of production, ratio averages of lagged endogenous variables, and long- and short-run measures of income. The variables were specified under the condition of availability of data, and in accordance with economic theory and prior knowledge of the industry.

The data were collected from the best available sources and conditioned by deflating the price and quantity variables with selected indexes. Estimates and standard errors were obtained for the coefficients of the structural relationships through the use of the limited-information, single-equation method of analysis.

These estimates proved to be, in many cases, inconsistent with the postulated behavior and with each other. In addition, the standard errors were frequently larger than the coefficients. The factors responsible for these results were indicated and a subjective evaluation given.

The limited-information, single-equation method does not appear to be a fruitful approach for investigation of the economic relationships of the minor or byproduct commodities. This failure was attributed to three possible shortcomings: (1) the stochastic model is an inadequate representation of the fats and oils economy, (2) the data do not adequately represent the variables, or (3) the conditioning of the data leads to biases in the estimates.

The evidence indicates that data limitations were the primary factors responsible for the poor estimates. Precise measures of the desired variables apparently are not available for the fats and oils sector of the economy. By inference, other secondary or byproduct commodities which are reported by agencies that use similar data-gathering technique, are likely to yield equally poor estimates of the structural parameters when this method of parameter estimation is used.

BIBLIOGRAPHY

Aitken, A. C., "On Least Squares and Linear Combinations of Observations," *Proceedings of the Royal Society of Edinburgh,* 1934-35.

Armore, S. J., *The Demand and Price Structure for Food Fats and Oils,* U.S. Dept. Agr., Technical Bulletin 1068, Washington, D.C., June 1953.

Banna, Antoine, *Oilseeds, Fats and Oils, and Their Products, 1909-1953,* U.S. Dept. Agr., Agricultural Marketing Service, Statistical Bulletin 147, Washington, D.C., 1954.

Cochrane, W. W., *An Analysis of Farm Price Behavior,* The Pennsylvania State College, School of Agriculture, Progress Report 50, May 1951.

Cromarty, W. A., "An Econometric Model for United States Agriculture," *Journal of the American Statistical Association,* Vol. 54, September 1959.

Drake, A. E., *Econometric Analysis of the Demand and Supply Relationships for Lard at the Retail Level,* Ph.D. thesis, University of Illinois, August 1958.

Fisher, M. R., "A Sector Model — The Poultry Industry of the USA," *Econometrica,* Vol. 26, January 1958.

Fox, K. A., "Factors Affecting Farm Income, Farm Prices, and Food Consumption," *Agricultural Economics Research,* Vol. 3, July 1951.

——— *The Analysis of Demand for Farm Products,* U.S. Dept. Agr., Agricultural Marketing Service, Technical Bulletin 1081, Washington, D.C., 1953.

Frisch, Ragnar, *Statistical Confluence Analysis by Means of Complete Regression Systems,* Publikasjon nr. 5, Oslo, Universitetets Økonomiske Institutt, 1934.

Girshick, M. A., and Haavelmo, Trygve, "Statistical Analysis of the Demand for Food: Examples of Simultaneous Estimation of Structural Equations," *Econometrica,* Vol. 15, No. 2, April 1947.

Grove, E. W., and Cannon, M. F., *Index Numbers of Farm Marketings and Home Consumption,* U.S. Dept. Agr., Agricultural Marketing Service, Agricultural Handbook 109, Washington, D.C., July 1956.

Heady, E. O., *Economics of Agricultural Production and Resource Use,* New York, Prentice-Hall, Inc., 1952.

Hicks, J. R., *Value and Capital,* 2nd ed., Oxford (Clarendon Press), 1953.

Hood, W. C., and Koopmans, T. C., *Studies in Econometric Method,* Cowles Commission Monograph 14, New York, John Wiley and Sons, Inc., 1953.

Judge, G. G., *Econometric Analysis of the Demand and Supply Relationships for Eggs,* Technical Bulletin 307, Storrs Agr. Exp. Sta., University of Connecticut, January 1954.

Kuznuts, G. M., "Measurement of Market Demand with Particular Reference to Consumer Demand for Food," *Journal of Farm Economics,* Vol. 35, December 1953.

Learn, E. W., "Estimating Demand for Livestock Products at the Farm Level," *Journal of Farm Economics,* Vol. 38, December 1956.

Mosack, J. L., *General Equilibrium Theory in International Trade,* Bloomington, The Principia Press, Inc., 1944.

Neiswanger, W. A., and Yancey, T. A., *Parameter Estimates and Autonomous Growth,* multilith report, University of Illinois, Department of Economics, 1958.

Rojko, A. S., "Econometric Models for the Dairy Industry," *Journal of Farm Economics,* Vol. 39, May 1957.

Shepherd, G. S., *Agricultural Price Analysis* (2nd ed., revised), Ames, The Iowa State College Press, 1947.

Staehle, H., "A Development of the Economic Theory of Price Index Numbers," *Review of Economic Studies,* Vol. 2, No. 3, June 1935.

Stone, Richard, *The Measurement of Consumers' Expenditures and Behavior in the United Kingdom, 1920-1938,* Cambridge University Press, 1954.

Tintner, Gerhard, *Econometrics,* New York, John Wiley and Sons, Inc., 1954.

————, "Static Econometric Models and Their Empirical Verification, Illustrated by a Study of the American Meat Market," *Metroeconomica,* Vol. 2, December 1950.

United Nations, Economic and Social Council, *Studies on Fluctuations in Commodity Prices and Volume of Trade,* Doc. E/CN. 13/L. 34, November 1956.

U.S. Dept. Agr., *Farm-Retail Spreads for Food Products,* Miscellaneous Publication 741, November 1957.

———— *The Fats and Oils Situation* (published six times a year).

———— *Major Statistical Series of the U. S. Department of Agriculture,* Agricultural Handbook 118, Vol. 1-9, 1957-58.

U.S. Dept. of Labor, "Store Samples for Retail Food Prices," *Monthly Labor Review,* Vol. 66, January 1947.

Wallace, T. D. and Judge, G. G., *Econometric Analysis of the Beef and Pork Sectors of the Economy,* Technical Bulletin T-75, Oklahoma State University, August 1958.

West, V. I., *The Short-Run and Long-Run in Demand Analysis,* mimeographed Research Report AERR-15, University of Illinois, Department of Agricultural Economics, February 1957

Working, E. J., *Demand for Meat,* Chicago, The University of Chicago Press, 1954.

APPENDIX TABLES

Appendix Table 1. — Data for the Variables in the Econometric Model, 1928-1960

Year	Use in products for civilian consumption				Home consumption	Use of fats and oils by industry	Wholesale price per pound			Wholesale price index numbers of food other than meat, poultry and fish	Wholesale price index numbers of industrial fats and oils
							Shortening				
	Lard	Shortening	Margarine	Meat			Animal fat	Hydrogenated	Margarine		
	(million pounds)				(1947-49 = 100)	(million pounds)	(cents)			(1947-49 = 100)	(1947-49 = 100)
1931	1,687	1,163	230	16,212	75.0	2,444	8.8	....	14.0	49.9	29
1932	1,799	936	202	16,359	72.8	2,223	5.9	....	11.2	41.1	23
1933	1,758	944	243	17,094	73.2	2,356	6.8	....	10.2	41.4	27
1934	1,637	1,197	263	18,187	73.1	2,548	8.6	....	9.8	48.4	32
1935	1,221	1,533	380	14,935	71.0	2,672	13.1	....	15.1	56.9	42
1936	1,442	1,580	391	16,727	72.6	2,844	12.2	....	15.3	55.2	42
1937	1,358	1,589	397	16,257	74.8	2,949	12.4	....	15.6	56.3	48
1938	1,436	1,499	385	16,500	77.6	2,712	10.2	....	14.6	49.6	37
1939	1,662	1,396	301	17,493	80.2	3,081	9.3	....	13.3	47.5	37
1940	1,901	1,185	318	18,812	81.4	3,085	9.1	....	11.8	48.6	38
1941	1,819	1,367	364	18,934	85.0	3,967	13.8	....	13.3	55.3	51
1942	1,688	1,237	364	18,451	92.5	3,576	17.0	17.8	15.1	63.5	64
1943	1,679	1,234	501	18,921	97.0	3,462	17.0	17.8	16.4	67.5	66
1944	1,583	1,147	497	19,827	101.0	3,716	17.0	17.8	16.5	66.6	66
1945	1,509	1,175	525	18,742	101.9	3,587	17.0	17.8	16.5	66.8	66
1946	1,640	1,409	533	21,344	101.2	3,502	21.1	19.7	23.5	83.6	80
1947	1,792	1,338	713	22,142	101.2	4,126	32.2	32.7	37.2	99.7	125
1948	1,850	1,410	887	21,120	98.5	3,946	33.7	32.9	32.7	104.5	112
1949	1,744	1,435	851	21,349	100.3	3,576	24.4	21.1	26.7	95.7	63
1950	1,891	1,656	918	21,721	98.7	4,140	25.5	23.2	27.9	99.1	69
1951	1,855	1,365	996	20,849	100.4	3,850	31.8	27.9	31.8	109.1	88
1952	1,817	1,562	1,219	22,399	103.5	3,593	25.2	21.6	26.9	109.0	56
1953	1,772	1,597	1,256	24,233	105.4	3,631	26.1	22.7	27.4	108.6	56
1954	1,627	1,870	1,346	24,613	106.7	3,517	27.9	23.2	26.6	109.9	60
1955	1,639	1,863	1,323	26,430	107.1	3,838	26.9	21.3	26.0	106.4	57
1956	1,627	1,797	1,354	27,553	113.1	3,962	28.9	22.9	26.9	107.0	57
1957	1,601	1,759	1,446	26,729	110.7	3,959	30.5	22.8	27.4	109.6	61
1958	1,657	1,935	1,549	25,963	115.7	4,011	30.1	21.2	26.5	112.5	62
1959	1,562	2,197	1,604	27,772	118.4	4,114	26.1	18.8	24.2	110.1	57
1960	1,397	2,238	1,676	28,615	120.7	4,236	....	18.6	22.2	111.4	49

(Table is concluded on next page)

Appendix Table 1. — Concluded

Year	Total disposable personal income	Population eating out of civilian supplies	Consumer price index numbers	Prices paid farmers for meat animals	Wholesale price index numbers (1947-49 = 100): All commodities	Wholesale price index numbers (1947-49 = 100): Processed foods	Wholesale price index numbers (1947-49 = 100): Meat, poultry and fish	Wholesale price index numbers (1947-49 = 100): Other than farm or food products	Lard, tierces, Chicago	Quantity of fats and oils exported	Total live-weight cattle, calves, sheep, and lambs	Total live-weight of hogs slaughtered	Production: Food fats and oils, excluding butter and lard	Production: Nonfood fats and oils, excluding inedible tallow and grease	Production: All food except meat animals
	(billion dollars)	(million)	(1947-49 = 100)	(1910-14 = 100)					(cents)			(million pounds)			(1947-49 = 100)
1926	76.4	117.4	75.6	...	....	....	....	....	....	....	......	......	.....	.....	.....
1927	76.7	119.0	74.2	...	....	....	....	....	....	....	......	......	.....	.....	.....
1928	78.7	120.5	73.3	...	....	66.3	53.5	66.4	11.2	....	......	......	.....	.....	.....
1929	83.1	121.8	73.3	...	....	58.5	51.0	65.5	10.9	....	......	......	.....	.....	.....
1930	74.4	123.1	71.4	...	....	53.3	46.1	60.9	9.8	....	......	......	.....	.....	.....
1931	63.8	124.0	65.0	91	47.4	44.8	35.3	53.6	7.2	819	14,326	15,769	1,808	335	75.6
1932	48.7	124.8	58.4	63	42.1	36.5	27.2	50.2	4.2	802	13,960	16,121	1,902	289	73.3
1933	45.7	125.6	55.3	59	42.8	36.3	23.4	50.9	4.8	835	15,157	16,553	1,765	299	69.1
1934	60.0	126.4	57.2	68	48.7	42.6	29.4	56.0	7.4	621	16,739	15,003	1,620	389	66.9
1935	58.3	127.2	58.7	115	52.0	52.1	44.2	55.7	13.6	208	16,356	10,267	1,630	456	71.7
1936	66.2	128.1	59.3	118	52.5	50.1	41.1	56.9	10.7	232	17,826	13,067	1,925	494	65.5
1937	71.0	128.8	61.4	130	56.1	52.4	46.4	61.0	11.1	251	16,944	11,979	2,213	437	77.5
1938	65.7	129.8	60.3	113	51.1	45.6	39.0	58.4	7.7	326	16,761	13,456	2,477	449	77.7
1939	70.4	130.9	59.4	110	50.1	43.3	36.1	58.1	6.0	554	16,775	15,303	2,385	520	78.4
1940	76.1	132.1	59.9	108	51.1	43.6	34.3	59.4	5.0	423	17,065	17,695	2,265	619	81.3
1941	93.0	131.8	62.9	143	56.8	50.3	42.3	63.7	8.6	629	18,867	16,758	2,580	756	84.8
1942	117.5	131.5	69.7	186	64.2	59.1	52.3	68.3	11.8	889	20,899	18,911	2,760	958	93.9
1943	133.5	128.9	74.0	202	67.0	61.6	51.6	69.3	12.8	1,441	20,770	23,412	3,219	1,042	91.9
1944	146.8	128.6	75.2	190	67.6	60.4	49.6	70.4	12.5	1,511	23,096	23,282	2,913	1,124	98.6
1945	150.4	129.1	76.9	207	68.8	60.8	50.4	71.3	12.8	996	24,987	18,013	3,260	856	99.2
1946	160.6	138.4	83.4	248	78.7	77.6	68.2	78.3	19.1	780	22,596	18,827	2,889	910	100.9
1947	170.1	142.6	95.5	329	96.4	98.2	94.4	95.3	22.5	884	24,637	18,321	3,335	832	97.6
1948	189.3	145.2	102.8	361	104.4	106.1	109.8	103.4	20.3	940	21,553	17,552	3,808	1,125	103.6
1949	189.7	147.6	101.8	311	99.2	95.7	95.8	101.3	11.3	2,248	21,243	18,193	4,593	1,211	98.9
1950	207.7	150.2	102.8	340	103.1	99.8	101.5	105.0	11.8	2,045	21,142	18,991	4,468	1,358	97.9
1951	227.5	151.1	111.0	409	114.8	111.4	116.7	115.9	16.1	2,446	19,322	20,554	4,718	1,415	94.7
1952	238.7	153.4	113.5	353	111.6	108.8	108.3	113.2	9.9	2,279	21,181	20,540	4,958	1,055	102.9
1953	252.5	156.0	114.4	288	110.1	104.6	93.0	114.0	11.9	2,655	27,132	17,479	5,389	1,078	105.5
1954	256.9	159.1	114.8	283	110.3	105.3	91.9	114.5	17.0	3,935	28,388	17,188	5,505	1,434	107.7
1955	274.4	162.3	114.5	246	110.7	101.7	84.8	117.0	11.8	4,101	29,332	19,270	5,961	1,537	107.4
1956	292.9	165.3	116.2	235	114.3	101.7	81.6	122.2	12.0	4,950	30,917	19,814	6,476	1,714	112.3
1957	308.8	168.4	120.2	275	117.6	105.6	91.9	125.6	13.0	4,664	30,016	18,360	6,746	1,621	110.1
1958	317.9	171.4	123.5	335	119.2	110.9	106.7	126.0	12.4	3,893	27,466	18,121	7,005	1,543	119.7
1959	337.3	174.7	124.6	313	119.5	107.0	98.2	128.2	8.8	5,376	27,233	20,774	8,132	1,705	117.3
1960	354.2	178.2	126.5	296	119.3	107.7	96.7	128.3	9.7	5,956	29,573	19,955	8,580	1,485	121.6

Appendix Table 2. — Per Capita Production of Edible and Inedible Fats and Oils; Data Used in Figure 1

Year	Cotton-seed oil	Soybean oil	Lard	Butter	Other edible oils	Total edible fats and oils	Inedible tallow and grease	Linseed oil	Coconut oil	Other inedible oils	Total inedible fats and oils
			(pounds)						(pounds)		
1931	11.4	.3	18.6	14.5	2.9	47.7	7.1	4.2	2.5	1.8	15.6
1932	12.6	.3	19.1	14.9	2.3	49.2	6.8	2.6	2.1	1.3	12.8
1933	11.1	.2	19.7	15.2	2.7	48.9	7.4	3.2	2.9	1.7	15.2
1934	9.7	.3	16.5	14.6	2.9	44.0	8.1	2.9	2.3	2.4	15.7
1935	9.3	.8	10.0	14.0	2.7	36.8	5.5	3.9	2.0	3.4	14.8
1936	9.7	1.8	13.1	13.6	3.5	41.7	6.4	3.6	2.0	4.0	16.0
1937	12.6	1.5	11.1	13.3	3.1	41.6	6.6	5.2	2.1	3.6	17.5
1938	12.9	2.5	13.3	14.0	3.7	46.4	7.2	3.4	2.2	2.9	15.7
1939	10.6	3.5	15.6	13.6	4.1	47.4	8.6	4.3	2.1	3.4	18.4
1940	9.6	4.0	17.3	13.6	3.5	48.0	10.4	4.6	2.6	2.9	20.5
1941	10.6	4.4	16.9	13.9	4.6	50.3	11.8	6.6	2.4	3.6	24.4
1942	10.5	5.8	18.3	13.0	4.7	52.3	13.2	7.3	.8	2.8	24.1
1943	10.2	9.6	22.2	12.6	5.2	59.8	12.8	7.1	1.1	2.7	23.7
1944	8.8	9.7	23.7	11.4	4.2	57.8	15.1	7.3	1.0	3.4	26.8
1945	9.9	10.8	16.0	10.6	4.6	51.9	13.6	4.1	1.2	3.7	22.4
1946	7.0	10.5	15.4	8.7	3.4	45.0	12.0	4.2	2.5	2.3	21.0
1947	7.8	10.8	16.8	9.3	4.7	49.4	14.2	3.2	5.6	2.3	25.3
1948	10.1	11.0	16.0	8.3	5.1	50.5	13.4	5.0	3.8	2.7	24.9
1949	12.1	12.6	17.2	9.2	6.4	57.5	14.4	5.0	3.7	2.8	25.9
1950	10.7	13.8	17.5	8.8	5.2	56.0	15.1	5.0	3.7	5.3	29.1
1951	9.4	16.4	18.9	7.7	5.5	57.9	14.9	5.0	3.4	5.2	28.5
1952	11.2	16.2	18.8	7.4	5.0	58.6	15.1	3.6	2.8	3.8	25.3
1953	12.0	16.1	15.1	8.3	6.4	57.9	17.2	3.2	2.7	4.1	27.2
1954	12.6	14.9	14.6	8.2	7.1	57.4	16.8	4.1	2.7	5.3	28.9
1955	11.2	17.4	16.4	7.7	8.2	60.9	18.3	3.8	2.7	6.0	30.8
1956	11.1	19.4	16.7	7.6	8.7	63.5	19.5	3.8	2.5	6.8	32.6
1957	9.3	20.6	15.2	7.4	10.0	62.5	18.5	3.4	2.5	6.4	30.8
1958	8.4	23.0	14.2	7.1	9.5	62.2	17.1	2.7	2.4	6.5	28.7
1959	9.7	24.8	16.0	6.6	12.0	69.1	18.6	2.8	2.6	7.0	31.0
1960	10.2	24.5	14.6	6.7	13.4	69.4	19.6	2.1	2.8	6.3	30.8

Appendix Table 3. — Total Domestic Fats and Oils Supply and Distribution; Data for Figure 2

Year	Domestic production	Imports	Stocks January 1	Total supply	Exports	Domestic disappear-ance
			(million pounds)			
1931	7,136	1,755	1,617	10,508	819	7,994
1932	7,272	1,288	1,695	10,255	802	7,638
1933	7,377	1,743	1,814	10,934	835	7,789
1934	6,966	1,486	2,310	10,763	621	8,219
1935	5,845	2,538	1,923	10,306	208	8,325
1936	6,669	2,289	1,773	10,731	232	8,698
1937	6,655	2,726	1,801	11,182	251	8,879
1938	7,396	1,815	2,052	11,263	326	8,677
1939	7,849	1,862	2,260	11,971	554	9,206
1940	8,350	1,651	2,211	12,212	423	9,298
1941	8,941	1,907	2,491	13,339	629	10,472
1942	9,576	989	2,239	12,804	889	9,917
1943	10,398	966	1,998	13,362	1,441	9,731
1944	10,497	992	2,190	13,679	1,511	9,998
1945	9,301	904	2,170	12,375	996	9,670
1946	8,801	812	1,709	11,322	780	9,303
1947	9,912	1,358	1,239	12,560	884	10,313
1948	10,405	1,290	1,312	13,007	940	10,371
1949	11,828	1,104	1,696	14,628	2,248	10,199
1950	12,056	1,320	2,178	15,554	2,045	11,523
1951	12,414	1,160	1,986	15,560	2,446	10,751
1952	12,341	1,001	2,363	15,705	2,279	10,762
1953	12,806	1,001	2,664	16,471	2,655	10,805
1954	13,259	994	3,012	17,265	3,935	11,065
1955	14,370	1,047	2,264	17,681	4,101	11,612
1956	15,435	983	1,982	18,400	4,950	11,736
1957	15,287	1,019	1,734	18,040	4,664	11,731
1958	15,143	1,028	1,662	17,833	3,983	12,210
1959	17,048	1,032	1,791	19,870	5,376	12,423
1960	17,352	1,074	2,337	20,763	5,956	12,694
1961	......	.....	2,137	......	.....	......

Appendix Table 4. — Per Capita Utilization of Edible and Inedible Fats and Oils; Data for Figure 3

Year	Lard as lard	Short-ening	Marga-rine (fat content)	Butter (fat content)	Other food uses	Total (edible fats and oils)	Soap	Drying oils	Other industrial uses	Total (inedible fats and oils)
	(pounds)						(pounds)			
1931	13.4	9.2	1.6	14.5	5.1	43.8	12.4	4.9	2.1	19.4
1932	14.4	7.5	1.3	14.9	4.8	42.9	12.1	3.8	1.8	17.7
1933	14.0	7.5	1.5	14.7	5.3	43.0	11.6	4.4	2.8	18.8
1934	13.0	9.5	1.6	15.0	5.4	44.5	13.0	4.8	2.4	20.2
1935	9.6	12.1	2.3	14.2	5.9	44.1	11.7	5.7	3.6	21.0
1936	11.3	12.3	2.6	13.5	6.0	45.7	12.4	6.2	3.6	22.2
1937	10.5	12.3	2.6	13.5	6.6	45.5	12.8	6.6	3.5	22.9
1938	11.1	11.5	2.4	13.4	6.9	45.3	12.7	5.3	3.0	21.0
1939	12.7	10.7	1.8	14.0	7.2	46.4	13.9	6.3	3.4	23.6
1940	14.4	9.0	1.9	13.7	7.4	46.4	14.1	6.1	3.1	23.3
1941	13.8	10.4	2.1	13.0	8.2	47.5	17.3	8.1	4.7	30.1
1942	12.8	9.4	2.3	12.8	7.6	44.9	15.1	7.2	4.9	27.2
1943	13.0	9.6	3.2	9.5	6.7	42.0	14.3	6.5	6.1	26.9
1944	12.3	8.9	3.2	9.6	6.9	40.9	16.0	6.6	6.2	28.8
1945	11.7	9.1	3.4	8.8	6.2	39.2	14.3	6.3	7.3	27.9
1946	11.8	10.2	3.0	8.5	6.4	39.9	12.5	6.6	6.2	25.3
1947	12.6	9.4	4.1	9.0	6.9	42.0	15.7	7.1	6.2	29.0
1948	12.7	9.7	5.0	8.1	7.1	42.6	14.0	7.4	5.8	27.2
1949	11.8	9.7	4.7	8.5	7.9	42.6	11.9	6.5	5.8	24.2
1950	12.6	11.0	5.1	8.6	8.6	45.9	12.0	7.9	7.7	27.6
1951	12.3	9.0	5.4	7.7	7.7	42.1	10.0	7.5	8.1	25.6
1952	11.8	10.2	6.5	6.9	8.7	44.1	8.8	6.6	8.0	23.4
1953	11.4	10.2	6.6	6.8	9.1	44.1	8.3	6.8	8.2	23.3
1954	10.2	11.8	6.7	7.2	9.5	45.4	7.4	6.3	8.5	22.2
1955	10.1	11.5	6.6	7.2	10.5	45.9	6.9	6.8	10.0	23.7
1956	9.8	10.9	6.7	7.1	10.9	45.4	6.3	6.6	11.1	24.0
1957	9.5	10.4	7.1	6.8	10.8	44.6	5.9	6.0	11.6	23.5
1958	9.7	11.3	7.3	6.8	11.0	46.1	5.3	5.4	12.7	23.4
1959	9.0	12.6	7.3	6.4	10.6	45.9	4.9	5.2	13.5	23.6
1960	7.9	12.6	7.6	6.3	11.4	45.8	4.9	4.6	14.5	24.0

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